THE TEACHING OF DESIGN:

A COMPARATIVE STUDY OF BEGINNING CLASSES

IN ARCHITECTURE AND MECHANICAL ENGINEERING

by

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ABSTRACT

Documented in this report is an investigation of design teaching in architecture and mechanical engineering, two professions which have traditionally included the subject in their educational programs. A definition of design is first proposed, and generic issues relating to the evaluation and teaching activity in the field are presented. The historical precedent for design teaching, focusing on academic instruction in architecture and engineering, is described, followed by a closer look at the evolution of design subjects in the curricula of the two professions at M.I.T.

Two design classes, one each in mechanical engineering and architecture, were observed as case studies for understanding design teaching as it is presently done. The teaching was observed over an entire semester; observation data was supplemented by information from interviews with the faculty and students involved. Students, in end-of-term interviews, were asked to respond to repertory grid tests around teachers and students, to open-ended questions, and to an informal design experiment.

The report concludes with a comparative analysis of the two cases, elaborating on several differences and three major similarities in the situations observed: (1) design was taught as problem-solving; (2) design was taught through criticism of the student's work; and (3) design teaching involved simultaneous use of visual, verbal, and/or mathematical languages. Implications of these findings and questions for future research are also proposed.

The appendices contain material from the classes observed, examples of interview materials, and a sampling of responses to the informal design experiment.

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I.

ORIGINS AND METHODS OF THE STUDY

The study documented in this report stems from an interest in the teaching of architecture. From an undergraduate and a graduate education in the professional aspects of architecture, I began the work documented here for the opportunity it presented to learn something about design education without being either a student or a teacher in the classroom. I hoped, through involvement with this research, to investigate certain aspects of the training commonly given architectural students in this country in order to understand some of the issues involved more clearly.

The focus of this work is on design and the way it is taught. Design instruction is, for the architectural student, the largest single component of his professional education, occupying at various schools from one-third to one-half or more of the curriculum time. It is thus the most distinctive characteristic of architectural education; just as the image of an engineering student has always included a slide rule (until recent times, when the slide rule has been replaced by an electronic calculator), so too has the archetypical architectural student seldom existed away from his drafting table in the studio. The studio method of design teaching also has a long history in architectural education; it is virtually as old as is academic instruction itself. Despite (or perhaps because of) its venerable tradition, the studio has not, to my knowledge, been the subject of inquiry into its methods or the kinds of learning which go on there. Information on the learning process involved in the development of design behavior is limited; cognitive psychology seems to offer no comprehensive insights on the complex ways in which adults acquire knowledge about design activity.[1] As an entry point to this uncharted terrain, therefore, I chose to examine, in a descriptive vein, the teaching of design as it is presently done.

The importance which architecture attaches to design instruction is perhaps unique among the professions. Aside from architecture, however, the other major discipline which has traditionally recognized the importance of design in its professional work has been engineering, and it was to this field that I chose to look for a comparative case of design teaching. It was believed that, in spite of the surface differences which identify the "engineering" or "architectural" character of design in the two professions, the underlying concepts of design which both attempt to communicate are the same, making a comparative study possible. (These will be elaborated further in Chapters 2 and 5.)

A comparative study of these two fields was thought to afford several advantages. First, the two disciplines represent contrasting models of design instruction. In engineering, design is considered as an integral part of a particular subject matter, seldom considered apart from analytical or theoretical studies of a given topic. The curriculum, organized around topics such as engines, transmissions, or processing plants, thus includes design education dispersed in a number of subjects. Architecture tends to arrange its curriculum around process, isolating design from theoretical or analytic studies and considering design almost independently of subject matter. Design exercises occur in a subject context, but specification of that context seems not to be of primary importance to architects. For example, the architecture curriculum studied stipulates the number of semesters of design to be taken rather than specifying what their content should be; it is theoretically possible (but not likely) that a student might design only housing, or theatres, or office buildings, in his several semesters of design work.

A second advantage accruing from a comparative study was that the issue of design was pulled more sharply into focus. For a researcher accustomed to the normal procedure of the studio, the relative unfamiliarity of the engineering design laboratory provided a stimulus to re-examine certain features of the architecture situation which might otherwise have passed as incontestable facts. In the search for parallels between the two cases, unexpected insights on design were found which might not have been detected without the comparative situation. And the condition of having two disciplines to study helped prevent the work from becoming bound up in issues peculiar to one field or the other. (This 'advantageous' feature can also be seen as a drawback: a number of interesting issues not directly related to design work were not explored because they did not advance the comparative inquiry.)

Above all, however, it seemed worthwhile to examine the teaching of design. In both architecture and engineering, design instruction is to a large extent dependent on the teacher; he provides for the students the major access to information about design and the process by which it is done. Even when textbooks do exist (as they did in the engineering case), these do not replace the live instructor in the classroom, particularly when guidance and criticism of the work are required. Design work in both fields is characterized by the instructors as a highly personal process which to date has defied adequate description or reliable modelling; its teaching is accomplished primarily through one-to-one interaction between the instructor and the student. The design instructor thus appears to be of central importance in the teaching of design, and his behavior is consequently significant. Design students must rely upon him to a greater extent than would students upon a lecturer in a typical classroom situation.

Education involves the dual process of teaching and learning. In the classroom, in addition to the teacher's interaction with students, there is also extensive peer group interaction among students which contributes significantly to the learning experience. The primary effort of this study, however, was directed to the teaching of design, not the learning. For a solo researcher, it was the half of the duality most accessible:

the activity was observable and confined to a given place (the classroom) and time (the class meeting hours) for a finite duration (in this case, one semester). A thorough study of the corresponding process of student learning, which can take place in a number of settings over an indeterminant time frame according to the individual, would require a range of research techniques, including some evaluative mechanisms, that this investigator did not feel equipped to undertake.

This study chose to observe two beginning design classes at the same university, one class in architecture and one in mechanical engineering. Beginning classes were decided upon as it was believed there one might find more attention given to fundamentals of design than to discipline-specific matters, which might receive greater emphasis in advanced subjects. Furthermore, at the beginning level, it was thought that the initial degree of design sophistication of the students in the two classes might be more nearly equal than with more advanced subjects, thus allowing comparative comment on the teaching methods used to increase the students' understanding of and competence in design work.

The architecture studio was one of four being taught in the term. It was selected because (1) the instructor was a highly respected, experienced teacher and an example of teaching excellence was desired; and (2) the studio's approach represented a widely used teaching method, utilizing a number of problems around a typical elementary subject (residential design), and employing both group and individual work under the direction of the instructor. Selection of the engineering subject was a bit more complicated: to accommodate the researcher's limited comprehension of technical matters, the search was confined to the departments of civil and mechanical engineering, where the physics, structures, and mechanics from an architectural background would qualify one to understand and appreciate the work being done. The decision to remove from consideration those engineering fields (such as electrical engineering) where design activity is carried out around non-physical objects (such as a computer program) was to some degree an arbitrary one, reflecting the investigator's preference for artifacts and devices. A further requirement for selection was that the subject should teach design at least in part through a project laboratory or similar method where the students could work individually with the instructor. A number of engineering subjects involving design provided no organized time for student work in the classroom; and it was felt that the opportunities for observing teacher-student interactions around work in progress, which is the heart of studio instruction in architecture, would be rather limited if no class time were devoted to this. Maintaining a comparative basis for the study would be difficult under such circumstances. A class in mechanical engineering emerged as the only subject which fulfilled the above criteria; most fortunately, as was the case with the architecture studio, the instructor in charge agreed to cooperate in the research effort.

Three basic strategies were employed in the research:

(1) An historical investigation of the precedent for design teaching in architecture and in engineering, along with

reading of the various writings on design;

(2) Observation of the two case studies of beginning design classes; and

(3) Interviews with faculty and students involved in the classes observed.

(1) Sources for the historical investigation of design teaching included writings about architectural and engineering education, studies of professional education in the two fields in the United States, articles in journals of architecture and engineering education, and the curriculum and course descriptions of the university's catalogues at five year intervals since 1861.

(2) The approach taken for the field research portion of the study was that of observation of the two cases over the entire term. With the exception of four days, every class meeting of the two subjects was attended by the observer. The choice of observation techniques was influenced by reading of the work in participant-observer studies by Becker, Hughes, Geer, and Strauss (1961), Schwartz and Schwartz (1955), Snyder (1971), Kahne (1969), and others. It was also affected by the "illuminative evaluation" concept of Malcolm Parlett, under whose guidance a preliminary study was carried out in the preceeding semester; he advocates examination of the larger learning "milieu" when studying educational innovations rather than relying on results from seemingly controlled experiments.

In observing design teaching, an attempt was made to follow the methods of "grounded theory" advanced by Anselm and Strauss (1967), allowing the findings to emerge from the study instead of advancing hypotheses beforehand and then looking for data to confirm or disprove the theoretical positions taken. This is not to imply that there were not some preconceptions held by the observer; in the course of the work, however, most of these have been replaced by far richer and more trenchant notions arising from the observed material.

(3) Interviews were of two types: those for teachers and those for students. Teacher interviews were the more informal of the two and were held at various intervals before and during the term, covering such topics as intentions and appraisals of the class. In addition to the miscellaneous conversations with students as the semester advanced, there was an attempt to interview students at greater length at the semester's end. Towards this goal, interviews were arranged with eight out of the twelve engineering students and sixteen out of the seventeen architecture students. (Two of the former group did not subsequently come to an interview.)

The student interview consisted of four sections. It opened with a brief introduction of myself and a summary of the intent of the research; although these topics had been explained once before, at the beginning of the term, and the class had grown accustomed to seeing the observer in class, it was found that many students had only vague understandings of the investigation which was being carried out. After clarifying these issues, the student was asked to respond to two Repertory Grid Tests which attempted to elucidate concepts of good and bad teachers and students. (Appendix D contains an explanation and example of these.) These tests, based on formats developed by George Kelly, allowed students to talk about specific people whom they considered to be good or bad in such a way that their constructs associated with excellence (or the lack of it) could be identified without revealing the names of the individuals concerned. Similar repertory grid tests used by Kelly and others have been shown to be a non-intrusive method of obtaining information. The tests also provided a structured opening for the interview, getting the students to think critically and specifically about the teachers and students with whom they had had experience.

The Repertory Grid Tests were followed by a series of open-ended questions which touched on a variety of issues from both classes. These were selected so that the student could talk about issues from the term which were important for him, as well as cover some topics desired for comparative purposes. The order of the questions varied slightly from interview to interview, but the general sequence was:

(1) How has the semester been for you? Would you care to talk a bit about the design class?

(2) What do you think you have learned?

(3) Can you cite a specific instance when you felt that you had learned somthing, large or small?

(4) Could you describe the process you go through when designing something?

(5) How would you define design?

(6) What was it that got you interested in engineering/architecture? What do you see yourself doing after graduation?

Student response to these questions was recorded by handwritten notes.

The final section of the interview consisted of an informal design experiment. Students were handed a blank tablet of 8 1/2" x 11" paper and asked to design a chair. This item was selected because it was a common object, not difficult to draw, which exists in a wide array of contexts and seemed to favor neither architectural nor engineering interests. The intent here was to see if students did indeed follow the design process just described in response to questions about it and also to test if students had learned about defining design problems, a skill not specifically taught in either design class. The student's working method and subsequent questions (if any) were noted and the resulting design turned over to the interviewer. (Appendix E contains a summary of responses.)

For the next part of the informal experiment, students were asked to list the kinds of information they would want to have if they were to design a pair of shoes. An actual shoe design was not requested, just a listing of factors thought to be necessary for doing the design. As with the chair question, shoes were selected because they were everyday items for which there were thousands of designs. The intent in asking this question was to ascertain that the student could identify some kinds of information which a designer might use in working on an unspecific design problem; it was hypothesized that some students would realize that the information utilized in designing a pair of shoes bore a certain resemblence to the kinds of information they might have used in designing a chair. Specifically, an indication of awareness of the design's interface with a user and a context was being looked for. (Again, the results are given in Appendix F.)

The informal experiment and the interview concluded with a two-dimensional design exercise. Students were given a stack of six rectangles cut from a 4" x 6" note card and asked to arrange them on a blank sheet of the tablet in some manner which was pleasing to them. When a satisfactory configuration was achieved, the final product was secured in place with transparent tape. A wide variety of designs was thus produced (a selection is to be found in Appendix G); for this study, an observation of the way in which they were made is of more significance than the objects themselves. Evaluation of the designs produced is a topic for another investigation.

The entire interview required approximately two hours to complete:

5 minutes were alloted to the introduction;

55 minutes were needed for Repertory Grid Tests;

40 minutes were spent on open-ended questions; and

15 minutes were devoted to the informal design experiment.

Students were paid a small sum for taking part in the interview schedule; they also reported enjoying the experience.

In the descriptions of the cases, names given to faculty and students are fictitious.

II.

THE PROBLEM OF DESIGN

> Design (noun) 1. A plan or scheme conceived in the mind and intended for subsequent execution; the preliminary conception of an idea that is to be carried into effect by action; a project. 2. Contrivance in accordance with a preconceived plan; adaptation of means to ends; pre-arranged purpose. 3. A preliminary sketch for a picture or other work of art; the plan of a building or any part of it; or the outline of a piece of decorative work, after which the actual structure or texture is to be completed; a delineation, pattern.

The Oxford English Dictionary spends the better part of a page defining design. From the original Latin, designare (to mark out, trace out), came several Italian and French derivatives meaning variously to purpose, plan or to model, picture, portray. The English use of design combines both senses of the word, but it is more in accordance with definitions one and two above and less with the third definition that this paper will consider design. Many aspects of everyday life involve design - the arrangement of a bowl of flowers or of one's time during the day; the planning of a sand castle or an evening dinner party - and almost everyone is, in some sense, a designer. Anyone who has attempted to alter something towards a desired result, be it a better mousetrap or a more efficient use of time, has designed something.

There are certain attributes of design as understood in this project which are constant regardless of the size, scope, or particular nature of the thing being designed.

1. Design is a synthetic problem-solving process. As such, it involves formulation or setting of what the problem in need of solution is, along with the devising of means for its solution. In producing a design, there must be some purpose in the designer's understanding which the design will fulfill, some reason for which the design is needed. Creations not so clearly responding to a practical problem have frequently been regarded as fine art.

2. Design is done in a constrained situation. There are always limitations around which the designer must work - materials, skill, time, financial resources, societal pressures, geometry, climate, and so forth. The understanding of those constraints which establish the context for every problem is essential if a viable solution is to result.

3. The products of design activity are non-unique. The constraints of the design problem must not be so proscriptive as to admit only one possible solution: that is puzzle-solving. In design, there is never one "correct" answer; there is rather a range of acceptable solutions from which the designer or others can select.

Designers and the general public tend to be casual about their use of the word design; it is used to refer to activities from specifying to styling. The definition which this study has chosen for design incorporates the characteristics just explained: design is a synthetic problem-solving activity operating in a situation with multiple constraints and (often) conflicting values where the solutions are non-unique.

Design activity is thus profoundly linked with the exercise of judgement. If one defines a professional as a person who by training and experience has the expertise to make decisions on behalf of others, that is, to use his judgement, then design must be understood as an activity common to almost all professions. In a professional sense, design may be seen as the ability to understand problems presented by a client or society and to act on these using the skills of the profession to produce change towards a desired goal. As Herbert Simon has said, "The intellectual activity that produces material artifacts is no different fundamentally from the one that prescribes remedies for a sick patient or the one that devises a new sales plan for a company or a social welfare policy for a state."[2] On the basis that design is an important aspect of professional roles, arguments can be made that design is or should be fundamental to educational programs in the professions, a condition that does not exist at the moment. There are two professions, however, which have for some time recognized design as an integral part of their domain, and these two, engineering and architecture, are the subjects of this study into the way design is taught.

The position occupied by design in the educational programs of the two fields is of course somewhat different: in architecture, design has traditionally been the core of the professional program, consuming about a third of the allocated curriculum time and as much as two thirds of the student's actual time; in engineering, where the curriculum time devoted to design has been considerably less, information for and practice in designing have been contained in a number of subjects. But both architecture and engineering seem to face similar difficulties in finding ways to teach a process which seems to be elusive in its precise specification. In architecture, the dilemma has sometimes been handled by leaving the teaching of design to men identified through their academic or professional work as "great designers", presuming some of the master's talent at designing would rub off on the students if enough individual instruction and guidance were provided. Engineering, on the other hand, has until quite recently refrained from ambiguous design problems, preferring to teach design in the context of specific subject matter of, for example, valve gears or boilers, where the number and scope of problem variables could be more easily controlled.

Design instruction in both fields has suffered from a certain lack of status in the academic world, a condition which has caused architecture faculties to be regarded as inferior enterprises compared to other university departments, and designers on engineering faculties to take their place behind scientific or analytically-minded colleagues. Herbert Simon has noted this phenomenon and suggested a reason:

> As professional schools, including the independent engineering schools, are more and more absorbed into the general culture of the university, they hanker after academic respectability. In terms of the prevailing norms, academic respectability calls for subject matter that is intellectually tough, analytic, formalizable, and teachable. In the past, much, if not most, of what we knew about design and the artificial sciences was intellectually soft, intuitive, and cookbooky. Why would anyone in a university stoop to teach or learn about designing machines or planning market strategies when he could concern himself with solid-state physics? The answer has been clear: he usually wouldn't.[3]

In some ways, design instruction does not make an ideal candidate for inquiry into its methods. Design teachers, especially in architecture, regard their teaching as almost artistic instruction - intuitive, private, and tinged with mystique. Critical onlookers are not always welcome. Many teachers are satisfied with the present system of teaching and its results. And some are fearful that attempts to analyze the design process will lead to quantification and computerization. The experience with design methods experiments in the 1960's (during which attempts were made to rationalize all design decisions from the analytic breakdown of a problem) has not been forgotten; design methods produced no great architecture. And although design methods and other research may yet yield new insights for designers, it is obvious that the design process is more complex than was first imagined.

In other respects, however, the present condition of design instruction makes it a most promising candidate for research inquiry. It is, after all, taught in schools of engineering and architecture, and with the importance of design being recognized, if somewhat slowly, in other professions, it might be worthwhile if architecture and engineering could share their accumulated expertise on design teaching. More significantly, perhaps, some inquiry might produce evidence which would assist present design teachers in doing what they do more effectively and efficiently.

From the architecture side, the need for some consideration of design teaching has been voiced for at least forty years. Franke H. Bosworth and Roy C. Jones, architectural educators who were commisseioned by the

Carnegie Foundation in 1930 to make the first study of architectural education in the United States, noted that "the total amount of time given in the architecture curricula to design is larger than that given to any other subject....in the different schools this varies from 24 to 60 (percent of the technical curriculum)."[4] These gentlemen, in their visits to schools and in their interim reports to the Association of Collegiate Schools of Architecture, tried to find teachers who could explain what design was or describe how one taught it; their final report makes no mention of a satisfactory explanation or description. The next major study, written in 1954, was more direct. It concluded:

> In organizing its content, demonstrating its principles, and controlling the learning process, design teaching is perhaps the most backward phase of architectural education. The reasons for this are easy to ascertain. The fear of formulae, the difficulty of discussing emotional criteria, the fallaciousness and special pleading of past theories, the glorification of intuition, and an unfortunate aversion against study and research of such problems on the part of both teachers and practitioners, have left the theory of design and design teaching poorly defined and only partially understood.[5]

In 1962, a British study on the practical training of architects (and hence not charged with investigating design) wondered editorially why no one had inquired into the aims and methods of a subject demanding so much of the student's attention.[6]

As engineering has had a lower explicit curriculum investment in design education, its concern for design instruction has been correspondingly less. Statements paralleling those in architecture calling for an investigation of design teaching are not to be found; instead, there has been a gradual recognition that design instruction had significance.

Early studies of engineering education do not identify design teaching as a mode of instruction distinct from other classes with lectures, laboratory, and recitation periods. Indeed, from journal articles prior to the 1950's one would conclude that teaching English to engineers was a far more difficult issue than was teaching design. Explicit recognition that engineers were designers was given by the Jackson Report (1939):

> Engineering being a combination of science and art, requires of its followers the power to gather data exactingly; the power to test analytically, consider, and classify the data; the power to formulate premises from the data; and also the power to view the data with a synthesizing imagination so as to visualize a plan or plans for utilizing the formulated premises in the designing and embodying of economic and serviceable structures, machines, devices, processes, or operating organizations.[7]

The Report does not elaborate on the means by which the "synthesizing imagination" might be developed, however. The Grinter study (1955) was more specific about the existing state of design instruction:

> The capacity to design includes more than technical competence. It involves a willingness to attack a situation never seen or studied before and for which data are often incomplete; it also includes an acceptance of full responsibility for solving the problem on a professional basis. The design portion of many engineering curricula demands close scrutiny and continuing active change. The major department sequences in many instances are dull and uninspiring, utilizing practices long outdated. These are areas in which newly developed concepts, analytical techniques, and measurements should be brought to bear.[8]

Circumstances dictated that concerns about science in the curriculum would take precedence over concerns about design; engineering science, new concepts, and analytic techniques were taught, not in conjunction with design, but as ends in themselves. By 1974, the Hollomon Report, the most recent of a long series of reports on engineering education, noted that

> this shift in educational emphasis has weakened the central role of the art of engineering, which is characterized among other things by problem definition and problem solving, by design in the presence of constraint and by the ability and willingness to deal with ambiguity and uncertainty....It is one of the major conclusions of this report that we must move to reintroduce the "art" of engineering into engineering education.[9]

Some of the difficulty in dealing with design stems from its art-like qualities. Art, as distinguished from design, is generally less concerned with solving a practical problem than with expressing an idea, but both art and design share characteristics (contextural relationships and non-uniqueness) which give them similar difficulties with evaluation. It seems safe to say that one obstacle in design instruction is the troublesome nature of design evaluation; if one could be more precise about the desired qualities of design, one might be able to find ways of teaching these explicitly. Evaluation of design is intimately and intricately joined to the definition of what design itself is, what the values of the juror are, and what the cultural context in which he exists is; and when the basis of evaluation shifts, design (and with it design teaching) must be redefined. In art and in architecture, evaluation has traditionally been done by the deliberation of a panel of experts, a jury, in the absence of the designer, the idea being that the designed object stands on its own merits which the jury can determine by itself. Juries have long been excused from the most difficult task of judging, that of setting down criteria by which they determine the worth of a given design. In the past, decisions were justified by some familiar qualities, much discussed but seldom clearly stated: proportion, rhythm, harmony, scale, beauty. As long as even a vague understanding of these terms existed, a reasonably stable (albeit imitative) basis for design instruction was provided. Much of the success of the Beaux-Arts system of design instruction rested on the school's successful formulation and application of "rules" derived from past monuments regarded as being in "good taste." A didactic method existed for transmitting these concepts to students: art students began by copying drawings and memorizing idealized proportions of the human body; architecture students learned the idealized proportions of Greek and Roman temples as expounded by Vitrivius, Alberti, and other masters.

With the decline of this century of the Beaux-Arts system, its explicitly formulated design principles declined also. That this universal yardstick for design evaluation no longer exists is demonstrated by the experience of a modern embodiment of the time-honored evaluation process, the design awards given annually since 1953 by the American architectural journal Progressive Architecture. For the last twenty-two years, a group of from four to seven jurors, selected each year by the magazine from the ranks of eminent North American architects and engineers, has been empaneled to evaluate several hundred submissions of current work in design. The criteria used for selection of award and citation designs has, with rare exceptions, never been articulated; one is left to infer it from summaries of the jury's remarks. But these remarks are revealing about the jury's thinking on and definition of design and architecture. For the first decade, abstract form was the most important element in design evaluation.

> As in the past several years, interesting forms caught the jury's fancy, but not always to the extent of winning top honors; the reader will see that simple, well-articulated statements vie with more plastic solutions for Awards and Citations. In fact, one criterion remains clear year after year as these thoughtful Juries work: the simple, direct plan, the clear and forceful design statement, the uncluttered and uncomplicated solution will come forward through the examinations and discussions. The involved, picturesque, or simply startling project may cause long Jury discussions, but in the end it is usually discarded in favor of the direct search for beauty and the directly effective handling of space, with something like a sigh of relief. (1958 Jury)[10]

Similarly, the 1963 jury gave awards to projects which had "an extremely disciplined and well-defined program" where "the architect had taken a tough attitude toward it and then developed beauty and character out of working with the terms." Successful projects were said to be "solved with simplicity and executed with imagination and restraint" or to be an "enthusiastic and inspired response"; in contrast, unsuccessful projects were "personally expressionistic and heady" or "designed with wild - if not complete - abandon."[11] What was meant by any of these words and phrases was not elucidated further; though the difference between an "enthusiastic and inspired response" and one which was "personally expressionistic and heady" would have been most instructive. (In fact, further investigation of the jury process of decision-making about design might be of interest.) The premiated designs themselves are testamonials to the universal appropriateness of the right angle in plan, elevation and section, yet this is never mentioned as a criterion for selection.

By 1968, the evaluation criteria had changed perceptibly. Designs were considered in the context of the environment in which they would be placed and in terms of the users for whom the designs would function. Thus, a juror's comment on the first award project, a low income housing proposal for San Juan:

> What appeals to me is that it's not an insult to the people who are going to use it. An outside design force is not at work imposing a strange order; it comes out of a particular culture and its needs. And it's made to be lived in by people who aren't normally sensitive, or aware, or involved with anything called architecture.[12]

Gone is the preoccupation with searches for beauty; physical form was now measured, at least in part, by its responsiveness to its environment, users and use. This concern continues in 1973, as an extract of jury dialog shows. (The remarks pertain to a citation design for an elementary school.)

> A: It's an open space school. One roof and the berm. I think it's a very exciting experience.
> B: It's a space frame roof.
> A: These walls are fairly movable, removable - all of these partitions could come out and the spaces could be reassigned.
> B: I think it's responsive to the notion that a worthwhile educational experience is an evolving kind of thing.
> C: There are all kinds of spaces there.
> B: I think the exterior appearance is a bit disappointing.
> A: It's really all berm; there are no exteriors.
> B: Also, I think the scale of the school is successful. Although it isn't child scale, it isn't as forbidding as some.[13]

This interchange also exhibits some of the difficulties encountered when considering users and use. The juror must assign values which may or may not be significant to the actual user - movable partitions, and exciting interior space. As a surrogate user, he decides whether the scale is or is not that of a child, then decides whether or not this is important.

The logical extension of this kind of evaluation is to include users on the jury; in this case, some eminent educators and some schoolchildren in addition to the eminent designers might have provided insightful comment. (At present, however, graphic communication of architectural designs through the orthographic projections of plan, elevation and section hinders their easy comprehension by the non-architectural public. Models, computer-generated simulations, movies, or other visual communications might be considered.

The trend in deliberations seems to be away from situations where "it was assumed that anyone would know what was meant and that any explanation or justification of the jury's choices would be superfluous"[14] towards a more concrete specification of criteria for choice. This appears very difficult for the architectural design jury to accomplish, but the 1973 urban design jury was quite clear about its evaluation bases and priorities; one juror stated:

> I would first ask is it likely to be built? Second, is it appropriate that it should happen? Does it just prevent something terrible from happening or is it something that would make life more attractive? When dealing with urban design, another question that needs to be asked is will it be fun? Will it make passing through that urban setting more pleasurable than before? The last and equally important consideration is will it survive in its particular intended setting?[15]

A similar shift, from abstract ideal to contextural relatedness, appears to have occurred in engineering. One indication of this is the Creative Design Display, an annual undertaking of the Engineering Graphics Division of the American Society for Engineering Education, where student engineering projects are exhibited and evaluated according to certain criteria. Although the exhibit is only seven years old, there has in recent years been a shift in the criteria on which the judges make their appraisals. The older form had six categories for consideration:

> Problem statement - need (practicality), goal, design parameters;
>
> Conceptualization - development of a system physically, mathematically and/or graphically;
>
> Analysis - the conciseness and professional approach followed in arriving at a final concept;
>
> Creativity - evidence of creative thinking on the part of the designer;
>
> Final design - feasibility of the final result;
>
> Presentation - clear explanation of professional quality, conforming to contemporary engineering standards, reducing concept to practice.[16]

The newer form has eight categories, Presentation being split into two sections, verbal and graphic, and two other categories being added or redefined:

> Background - availability of other items or methods that may solve or nearly solve the problems and availability of methods or materials to meet each of the parameters;
>
> Final concept - determination of final concept considering side effects, societal, etc.[17]

Both of these redefined categories deal with context-specific attributes of the design: a recognition of previous approaches to the problem, awareness of existing solutions, and explicit consideration of the design's impact on the larger environment. Engineering designers seem to have arrived, as have many architects, at an awareness of contextual issues when evaluating designs.

The discovery of the context in which design operates - both its users and its environmental setting - has brought a new aesthetic to design judgments. Universal canons of beauty and good taste have been made relative, and evaluation processes which do not recognize this seem out of date. A splendid example of this is the "Graves Design Judgment Test" (published by the Psychological Corporation) which purports to evaluate an individual's design sense according to "the basic principles of aesthetic order - unity, dominance, variety, balance, continuity, symmetry, proportion, and rhythm,"[18] a universal set totally lacking contextural ties. The Test, which is nearly thirty years old, asks subjects to select one of two or three abstract compositions which have no apparent reason for existence according to their personal preferences; to score high, one must "know" to avoid axial symmetry, to prefer a golden section rectangle over a square, and to abide by a number of other formerly sacred principles of design. If one applies current design evaluation criteria, any or none of the choices could be considered "correct" or "good" design; it is impossible to say without knowing anything about the context for which the design is intended.

III.

ACADEMIC INSTRUCTION IN DESIGN

For the origins of present day design teaching in universities, one must refer back to the academies of art which developed during the Renaissance. Prior to that time, the only form of professional design education was the apprentice system: a prospective architect/engineer (the two professions being indistinguishable from each other at that time) would be apprenticed, usually for seven years, to a practicing master who would undertake to teach him the theoretical and practical sides of the art. In accordance with individual and regional variations, the instruction might cover such topics as drawing and painting, materials and methods of construction, geometry, mathematics, the classic orders of architecture, building design and ornament, the construction of machines of war, city planning, and the design of various mechanical devices. (The fragmentary documents remaining from Roman and medieval times, particularly the notebooks of Villard d'Honnecourt and Vitrivius' _Ten Books on Architecture_, show that these topics were commonly the domain of designers in pre-Renaissance times as well.) Apprenticeship provided a very direct and practical means of training new architect/engineers, yet the system had its drawbacks. Busy practitioners did not always have the time or the talent for teaching, and as the information about classic Greek and Roman building increased in the Renaissance, there was more information than before to teach. Moreover, the demand for skilled designers was increasing as princes sought to glorify their domains with art and new construction, yet the capacity of the apprentice system was limited by the supply of older masters.

To redress some of these difficulties and to relieve the individual masters of some time-consuming elementary instruction, architects and artists began to join together in the latter half of the sixteenth century to offer formal instruction for apprentices in academies. The movement started in Italy - Florence, Rome, and Milan - and by 1648 had spread to Paris where the Royal Academy of Painting and Sculpture had classes in drawing, geometry, perspective, and the orders of architecture. Academy instruction did not replace the apprentice system; it merely centralized some aspects of beginning instruction. The vast building programs of the French court created additional demand for architects, leading to the establishment of a school for architects separate from that of painters.

> In 1671, the founding at Paris of the Royal Academy of Architecture and the inauguration of its school gave momentous impulse to technical organization and education. Francois Blondel, its first professor, conducted a two-year cycle of classes with semi-weekly lectures. The program included arithmetic, geometry, perspective, stereotomy, mechanics, architectural theory, gnomonics, hydraulics, military architecture, and fortifications....The supplemental character of the program was emphasized by the academician's reservation that each would continue to instruct his own students in design in his own office.[19]

By the end of the century, the academicians had added a monthly program of design competitions where gold and silver medals were awarded to the entries judged best by vote of the entire academy; in 1720, an annual competition, The *Prix de Rome*, was added to select a student to be sent, on full scholarship, to the French Academy in Rome.

> The Rome School, which provided three years of what one may call post-graduate training, crowned the entire edifice of French academic training. A pilgrimage to that city had for long been regarded as a most useful part of any painter's education and the long residence of Poussin conferred especial sanctity upon the tradition. In Rome the main business of the student was copying. Colbert, in founding the School, had taken a severely practical view of the whole matter. The students were there, as he saw it, simply to provide Paris with facsimiles of everything that was valuable in Rome.[20]

The *Prix de Rome* winners in architecture used their not inconsiderable delineation skills to send back measured drawings of all the major Roman buildings and ruins in the city, along with drawings and plaster casts of column capitals and other ornament. Spurred by the discovery of Pompeii in 1748, drawing expeditions expanded their scope to document the ruins of Palmyra, Balbec, Athens, Spalato, and elsewhere; handsomely engraved volumes of these researches became the major architectural reference books for students and practitioners alike. Thus from the first, academic instruction in design was characterized by several traits which have not fully been discarded today in university schools:

1. Instruction in design was separate from the rest of the curriculum and seen as a matter to be guarded by the individual master designer.
2. Design teaching was accomplished through individual instruction for each student, not through group instruction.
3. Evaluation of design work was done through competitions judged by persons (jurors) not involved in the

instruction period during which the design was created.

4. Architecture of the past was seen as a more potent source for architectural design than architecture of the present; design was concerned chiefly with the clever or imitative adaptation of classic forms and ornament to new building needs.

While architects were occupying themselves with historical researches of antique buildings, they were ignoring other areas which were traditionally part of their domain; by looking so assidiously at classical ruins, they failed to see the scientific and technological advances which were happening in their own time. They scarcely noticed that a new breed of professional, willing to apply principles of the emerging sciences to societal problems, was arising. Engineering, which hitherto had been closely allied with architecture, was becoming an entity into itself. Military concerns were the first to organize as a separate body; in 1675 the French army's Corps de Genie was formed. Germany can claim the first engineering school, that at Braunschweig for mining and metallurgy (1745), but to France belongs major credit for developing the next half-century of engineering education. In 1747, Perronnet was made chief engineer of the French system of bridges and highways and charged

> with the direction and supervision of surveyors and designers of plans and maps of the roads and highways of the realm and of all those who are appointed and nominated to said work; and to instruct the said designers in the sciences and practices needful to fulfilling with competency the different occupations relating to the said bridges and highways.[21]

Perronnet's instructional system divided the engineers into three classes, based on ability and experience, with "exceptional rewards" for the outstanding students in each class. Instruction was given by professors of architecture and mathematics during the winter months; summers were spent working on projects under construction. Although this school began in 1747, it was not given official recognition until 1775 when it became the Ecole des Ponts et Chaussées. In contrast to early architecture schools, the first engineering schools arose, not as adjuncts to the apprenticeship system, but as self-contained units combining theoretical and practical instruction.

The French Revolution brought about the next major change in both architecture and engineering education. At that time, all of the schools operating under royal sponsorship ceased. The Ecole des Ponts et Chaussées and the Royal Academy of Architecture were replaced by the Ecole Centrale des Travaux Publiques, which had a three year curriculum in architecture and civil engineering, with architecture, including design, being taught through the department of mathematics and mechanics. This experiment was short lived, however; in 1795, scientists and engineers gained control of the curriculum, converting it into the world's first general engineering school, the Ecole Polytechnique. The school was modified to become a two year basic course to be followed by advanced work in the specific disciplines at regional state schools. Unfortunately, no advanced school for architecture was provided, so the architecture faculty regrouped itself around the disbanded Academy School and joined with several other art schools to become, in 1797, the Ecole des Beaux-Arts. Art and science had parted company in France.

It was the model of the Ecole Contrale, though, which was picked up and continued by the states of central Europe. The Bauakademie at Berlin (1799), the Polytechnic at Prague (1806), and the Polytechnic Institute of Vienna (1807) all were organized around a technical core from which architecture and engineering developed as specialties. The two and one-half year Bau-Academie curriculum thus covered:

mathematics

architectural, mechanical, topographical,
perspective, and freehand drawing

the physics of construction

statics and mechanics

building construction

the history of architecture

the requirements of design of both common
and monumental buildings

city planning

machinery

highway, harbor, and river works

as well as a term of office experience during the course.[22] This curriculum stood in sharp contrast to the architectural instruction of the same period at the Ecole des Beaux-Arts, which returned to the traditional patterns of the academy without including technical work in its curriculum. It is questionable what effect technical input in the Bau-Academie and Polytechnic School curricula had for German architects, for within several decades it was generally accepted that architecture students at the Polytechnic would supplement the design training received there with instruction which was closer in nature to that of the Beaux-Arts; "study in academy classes, in architects' offices, or in a meisterklasse conducted by an eminent practitioner."[23] The French division of art and science was probably a more accurate reflection of current practice:

> The scientific treatment and solution of the structural problems of statics and strength of materials permitted a more rational design of the structures, and this made it possible to cope with extensive and difficult structural tasks in an economic way, without prejudice to safety requirements. At the same time, however, it was now possible to design structures according to two points of view, different in principle: the one emphasizing the engineering aspect, i.e. structural analysis and calculation, and the other stressing the architectural aspect, i.e. the aesthetic appearance. All according to the nature of the task, the one or the other prevailed: the engineering aspect in the case of utility buildings, and the architectural aspect in the case of monumental buildings.[24]

In any event, it was the style and results of the French schools which made them the envy of Britain and the United States. Training for both architecture and engineering students in Great Britain was accomplished chiefly by the pupilage system (a variation of apprenticeship where the student pays a fee to a practitioner in exchange for instruction in his office) until well into the twentieth century. There, the traditional universities were slow to embrace experimental science and applied technology; and despite the architects' repeated pleas for a Royal Academy on the French model, one was not established until 1768, and even then it remained quite limited in offerings and enrollment. From The Complete Book of Trades or the Parents' Guide and Youth's Instructor, a work dating from 1842, one obtains a description of architectural education in England at the time.

> The youth desirous of becoming an Architect should be liberally educated, and in addition to the Latin language, he should be a master of French and Italian; have some knowledge of mathematics, geometry and drawing. The premium required with a pupil by a respectable master is from two to five hundred pounds: the youth will also require a considerable sum for the purchase of books, instruments and drawing materials. He must, during his apprenticeship, learn to make drawings from admeasurement, also to sketch picturesque buildings, columns, etc., he must be careful in observing the proceedings of workmen in every branch of business connected with buildings. When he is out of his pupilage, if he can afford it, he should spend a few months in Italy, to study the remains of the ancient masters, and the works of masters of a more recent date. On his return, if he has no private connexion, he will wait for an opportunity of competing with other architects for the execution of a public building. If his design be selected, and he complete the edifice, satisfactorily, his reputation becomes established, and he seldom lacks highly lucrative employment. But it is almost impossible for a man in the middle walk of life to afford the money to enable a youth to work his way in this arduous pursuit. If he have not the advantage of a capital to live on till he succeeds in business, the pupil, after he is out of his time, obtains employment as a drawing clerk in an Architect's office: and, during his leisure, makes plans and drawings for small builders, or is employed to measure and value their work. Some, by this means, get into extensive business.[25]

The United States, unhampered by centuries of university tradition, actually led Britain in the establishment of collegiate schools for engineering and architecture. As in France, the need for military engineers led them to have the first school (West Point, 1817) but other institutions were not far behind: Rensselaer School developed a civil engineering course, the first in the English-speaking world, in 1823. Wickenden, writing a century later, described early American engineering education as

> the outgrowth of a popular movement...to promote "the application of science to the common purposes of life." There was no thought in the beginning of creating any formal discipline for the profession of engineering; the aim was rather "to give farmers and mechanics such scientific education as would enable them to become skillful in their professions."...There was no foundation for a scheme of training by pupilage, as in England, and the engineering school arose by simple necessity. Models were borrowed from France, where higher technical education was highly developed, and the effort to apply science to the common purposes of life passed rapidly into the special form of a discipline for engineers. This in turn was quickly assimilated into the newly developing university system.[26]

Both the first American schools, West Point and Rensselaer, had founders who were familiar with the French Ecole Polytechnique: the curriculum, the textbooks, and on occasion, some faculty, came from Paris, as a student's description of West Point in 1824 reveals:

> The methods of instruction were entirely new, and textbooks very imperfect. The professors and teachers had themselves to learn the true use of the blackboard (an innovation in educational aids of the day), and the strict and detailed manner of demonstration. In algebra the best textbook that could be obtained was a poor translation of Lacroix. In geometry we had a translation of Legendre; in trigonometry, a translation of Lacroix; in descriptive geometry, a small work of Crozet, containing only the elements without application to the intersection of surfaces or to warped surfaces. These, with the whole of shades, shadows, and perspective, stonecutting, and problems in engineering, were given by lecture to the class.[27]

Until past the middle of the century, courses in civil engineering also offered the only formal instruction in architecture available in the United States; most of the curricula included courses in drawing, construction, and the orders of architecture in addition to their scientific and technical base. Although Thomas Jefferson has proposed a program in architecture for the University of Virginia in 1814 (to be, as in the Ecole Centrale, in the School of Mathematics), no one was found to teach the course. For American students, more detailed information about architecture had to come from copy books, mostly from England, or actual experience in an architect's office; not until the 1850's did an American (the first was Richard Hunt) attend the Ecole des Beaux-Arts. The school was known widely, however; in 1864, the newly-created American Institute of Architects requested the establishment of a national architectural school on the Beaux-Arts model.

That this did not happen is due to the passage by Congress in 1862 of the Morrill Land Grant Act, which provided the necessary financial resources for institutions "to promote the liberal and practical education of the industrial classes in the several pursuits and professions in life." The number of public and private universities offering courses in engineering grew rapidly, and the first U.S. schools of architecture were established: at MIT in 1861, the University of Illinois in 1867, and at Cornell in 1868. If not from the first, then very soon thereafter, all of them fell under the influence of the Paris Ecole des Beaux-Arts. American alumni of the Ecole increased considerably by the turn of the century; there were 10 Americans in the Paris school during the 1860's; 33 in the 1870's; 29 during the 1880's; and 152 in the 1890's. In the first decade of the twentieth century, over 350 Americans attended the Ecole des Beaux Arts.[28] In 1894, several Ecole men then in New York joined together to form the Society of Beaux-Arts Architects, in hopes of perpetuating the spirit of the Ecole in the architectural desert of America. This group shortly became the Beaux-Arts Institute of Design, which was to have profound influence on architectural design instruction for the next forty years as a de facto national school of architecture. Within the span of fifty years, the original unity of architectural and engineering education split into two distinct streams, one looking forward and one looking back. Burchard laments:

> Most of the architects in America (in the 1870's) were under the influence of English romanticism, but the engineering faculties, in so far as they taught design at all, learned on the classics as interpreted by Vignola. Conflict was bound to ensue. Architectural students fled abroad when they could and began their misguided worship of the Ecole des Beaux-Arts in Paris which few of them really understood. Had they but known it, American engineers had a fleeting chance to develop in nascent architects an understanding of the relation of technology to architecture. Instead, they themselves ignored the relationship, took refuge from it in aping the classics. Thus the architects were alienated both from engineering and from the growing activity of their times. The alienation left a stubborn residue in the mutual mistrust between architects and engineers. It meant that architects would never really understand their quarter-century, would try to deny what they did understand, and would usually join the anti-scientific and anti-rational forces of the day. The things they built would betray this all too clearly as would the experiments they failed to make. Most of all perhaps the attitude would be betrayed by the contempt in which architects and clients held the most important building types of their generation. Indeed, manufacturing seemed so vulgar as to be beneath the attention of most architects.[29]

A brief description of the teaching programs and methods of the Ecole des Beaux-Arts is appropriate. The school itself was used only for lectures and juries, while the real working parts of the Ecole were dispersed in some thirty ateliers scattered in nearby buildings. Architecture students attending the Ecole selected their own atelier, under whose patron they would do their design work for the length of their stay. Each atelier had students at all levels of experience, from beginning (nouveau) to advanced (ancien). Identical problems graded to the level of experience were assigned for all ateliers. Nouveau students worked on analytiques or order problems, elementary exercises to familiarize the student with the proper use of the orders of architecture, rendering techniques, and the compositional study of elevations; Second Class problems required the student to design simple buildings in both plan and elevation; anciens were given First Class problems, which involved larger buildings, studies in massing, and monumental conceptions. Design work, as in the old Royal Academy days, was evaluated through competitive juries of the work from all ateliers, and students progressed from level to level by the accumulation of points for first, second, and mentions on premiated designs.

> The problem method as developed by the Ecole consisted of a series of exercises progressing in content and difficulty.... In both classes, two-month major and 12-hour sketch problems were posed. Programs, prepared by the professor of theory, established the type of building to be studied, the areas of required rooms, and the site. The student was then required to solve these conditions schematically in an esquisse in 12 hours of strictly individual effort. In preparation for the esquisse, the title of the program was usually announced in advance, but no systematic discussion was provided to orient the student as to approach or fundamental data. It was assumed that the student, by attending the lecture course in theory of architecture, by personal observation of notable Parisian buildings, and by searching in architectural publications, could through his own effort gain sufficient command of data and principles to enable him to arrive at a definitive scheme. The necessity to do so was heightened by the strict prohibition of significant deviation from the esquisse during subsequent development of a problem....Problem development was probably the strongest feature of the Ecole design system....The endless succession of studies, progressing from small to final scale and from basic elements to intricate details, at its best set a standard of craftsmanship and thoroughness never before attained. Much of this care, however, was sacrificed to externals, the mosaics and entourage which made plans more readable,

> but which often led to a tapestry of abstract pattern that became an end in itself. Nor did the system discourage that weakness of human nature, the procrastinating trait, which transferred disproportionate effort to a final grand _charette_.[30]

To the _ateliers_ was delegated the teaching of all things which were contestable or subject to debate, i.e. design; the teaching of known facts, mostly history, theory, and some rudimentary structures, was accomplished through lecture.

As translated to the United States by the Beaux-Arts Institute of Design, the Beaux-Arts system concerned itself only with the design instruction aspects. Programs for the three classes of problems were sent out from the New York office to schools of architecture and to independent ateliers connected with professional offices; student work was then mailed back to New York for judging. Various prize competitions were established, the chief one being the Paris Prize (begun in 1902) which enabled the winner to make the grand tour of Europe and study with first class students at the Ecole des Beaux-Arts. By the early decades of the twentieth century, many American schools of architecture boasted at least one Ecole-trained professor of design and made use of the BAID programs for design instruction. Thus the isolation of architectural design from other studies, a legacy from the seventeenth-century academies of art, became the dominant characteristic of twentieth-century architectural education.

Documenting the corresponding development of engineering design instruction is somewhat difficult to do; from writings, it appears that engineers were more concerned with finding applications of discoveries in science and the development of new materials and processes than they were for teaching or theorizing about design. (See, for example, histories of nineteenth century technology.)

Subject matter, not process (analysis or synthesis), was the basis on which the curriculum was organized. In early studies of engineering education, design is not identified as a field of study, and design teaching is not discussed as a separate mode of instruction. Just what comprised engineering design instruction at the beginning of the twentieth century is only hinted at by the curriculum and textbooks. The engineering texts on machine design concern themselves with the elements of machines: fasteners, gears, transmissions, tolerances and fits, engines, and the like, with illustrations of typical parts, formulae, and tables for correct sizing of the various components. In many respects these texts seem analogous to the outstanding architectural treatise of the day, that of Guadet. Instead of machine parts and their proper assembly, Guadet covers building parts and the rules for assembling them. Neither set of books contained projects through which the principles expounded might be applied, nor was much indication given as to how this might be accomplished.

> Machine design...may be defined as the practical application of the Mechanics of Machinery to the design and construction of machines. It involves the determination of the structure, form, size, and relation of the various parts of a machine, in advance of its construction. While the laws of Mechanics of Machinery give us the underlying principles on which machine action rests, their practical application depends

> upon many modifying conditions. In some problems of Machine Design it is difficult, if not impossible, to apply the laws of Mechanics with accurate results, and recourse must often be had to judgment and experience.[31]

The Mann Report on engineering education (1918) criticized the schools for neglecting the integration of various kinds of engineering knowledge in problems given to students:

> With regard to materials, the schools do give careful instruction in the laws of physical science and in the properties and uses of materials. Students are taught the relative strengths of substances in the materials laboratory, kinematics teaches the principles of gearing, the shapes of gear-teeth are worked out in the drawing room, the chemical properties are taught in chemistry, mechanics deals with the forces required to overcome inertia, machine work is relegated to the shop, and so on. But seldom is all this information coordinated in a single practical problem, as determining whether mild steel, nickel steel, or phosphor bronze is the best thing to use in making a particular gear wheel; nor is the student ever asked to judge what combination is likely to produce the most valuable result for the price....Little consideration is given in courses in machine design to the comfort and safety of the operator.... Similarly the importance of good heating, lighting, ventilation, and sanitation in increasing the output of workers and in keeping them strong and healthy should always be taken into account. These human factors enter in large measure into the determination of the values secured for a given cost.[32]

Mann found the scarcity of problems involving judgement and thinking in all aspects of the curriculum to be one of the serious deficiencies of engineering programs. In contrast, Wickenden's comparative study of European and American schools a decade later reported on the attention given design in French curricula:

> The <u>project</u> is a full-scale engineering problem, including questions of selection, design and cost, which is assigned for individual work with little or no formal supervision

> by the teacher. The latter is an absentee, except during his lecture periods, and much occupied with active duties. He may spend one or two afternoons per month in the _salles d'etudes_, to afford students an opportunity for consultation, but for the most part the students are thrown on their own resources. Work of this character occupies the greater part of the student's time, apart from the _cours_ (lectures), in the final year.[33]

No corresponding program in American schools is documented, though in some cases the thesis fulfilled a similar function. Engineering design instruction appears to have been characterized by a certain narrowness, in part due to its close association with analytical study of the subject matter, while architectural design teaching developed elaborate program sequences which became increasingly devoid of analytic content.

While architects generated more rhetoric about design, they seem to be no more explicit than were the engineers when it came to describing how or explaining why design teaching was as it was. Problems such as "the decorative treatment of a wall fountain to end a vista," "a small private chapel on a country estate," and "a conclave building for the election of a sovereign pontiff" were considered appropriate for beginning, intermediate, and advanced students respectively, yet there seemed to be no reason beyond a simple concept of increasing size which guided the selection of problems. The Association of Collegiate Schools of Architecture's statement on design teaching, written in 1913 and used with minimal revision until after 1930, provided the nominal description of instruction.

> Design. This must be taught on the basis of problems requiring a solution, development and presentation by the

> student under criticism, accompanied by short problems to be carried out with no criticism until after the problems are turned in. As a condition precedent to receiving a degree the student must be able to solve satisfactorily problems of the first class, that is, single buildings or groups of public buildings of importance or other problems in composition of equal difficulty.[34]

Descriptions of the teaching itself are more remote. Professor Julien Gaudet, of the Ecole des Beaux-Arts and author of a widely used treatise on architecture, compared teaching to guidance by an older and more experienced friend of the student;[35] Professor William Boring of Columbia University, thought "it might well be likened to the Apostolic succession in which the transmittance of divine fire is accomplished in the laying on of hands by the master."[36] Bosworth and Jones, in their 1930 study of architectural education, found that

> The great critic never teaches architecture, he only suggests a method by which the problems of architecture may be attacked....The method has for him greater importance than the answer arrived at; the route taken, not the journey's end, is his objective.[37]

Unfortunately, the "route taken" is never better described, and the "journey's end" remained as the basis for evaluation by design. Conclusions of an ACSA roundtable discussion of design summarize better the prevailing attitude about design and design teaching:

> ...that the teaching of design cannot be mechanized any more than design itself can be mechanized. That while method, archaeology, logic and structure all play important parts, yet too much of them, too much of documents, travel, and knowledge may result in architecture losing that power to arouse an emotional reaction which all architecture must have over and above its strength and logic. A Greek column was designed as it was, not for literal strength, but for optical effect of strength; the Washington Union

> Station lobby might be seven feet high so far as affording circulation was concerned. ...the whole story of design was too big to tell in words, and needed time, feeling and experience to be wholly grasped.[38]

Most design teachers in engineering and in architecture were as vague as the teacher called upon at the 1931 ACSA meeting to talk about the subject: "He had difficulty defining design. As for himself, he had just always done it."[39]

In Germany, between the world wars, a different approach to design was developed at the Bauhaus. Under the leadership of Walter Gropius, the Bauhaus attempted to unite art and craft and, rejecting the neo-Classical revival of styles, to design for the aesthetics of modern machine-produced goods. Its first semester of design, the Vorkurs, introduced students to the study of forms and properties of design materials; exercises involved the use of wood, paper, clay, textiles, and paint, often in unorthodox ways. The Vorkurs, in fact, attempted to deny the student's previous knowledge and conditioned experience by providing a series of exercises for which there existed no design precedent. Using limited materials, surprisingly elegant designs were produced by students without "artistic" training, demonstrating to the satisfaction of the Bauhaus faculty that design abilities and instincts could be fostered through this kind of study.

The Second World War precipitated far reaching changes in both architecture and engineering education. In the former case, the educational grip of the Beaux-Arts Institute of Design, already weakened by the depression, economy and modern architectural developments in Europe, was finally broken as teachers from the Bauhaus arrived in the United States to assume leadership of leading architectural schools. In the latter case, the war brought out more dramatically than any educational study could have the inadequacy of engineering education; research and development programs associated with the defense effort were led by physicists, rather than engineers, because physicists had a superior grasp of scientific principles.[40] Not surprisingly, a major study of engineering education undertaken from 1952-1955 (the Grinter Report) had the "strengthening of work in the basic sciences, including mathematics, chemistry and physics" as its first recommendation. Engineering schools became heavily oriented to study and research in engineering science. And although the Grinter report also recommended "an integrated study of engineering analysis, design, and engineering systems for professional background," less attention than before was given to the problems of design teaching. The study of engineering design in other than a specific artifact context seems to date from the student protests of the late 1960's; the cries then against military research and ecological destruction being done by engineers led to reappraisal of teaching modes and the introduction of project-based design courses around real situations involving economic, political, social, and human values in addition to technical competence and calculations. Engineering design, in the sense <u>design</u> is construed in this study, is thus a comparatively recent addition to many curricula. Its teaching style follows the pattern established in architecture: students work individually or in small groups with occasional guidance and criticism from the teacher and/or outside consultants.

The influx of Bauhaus people and ideas into architecture schools had striking effect on the content of design courses particularly at the beginning level. Ideas and exercises from the Vorkurs became basic design subjects, taught instead of the orders of architecture in introductory classes. At upper levels of study, the Beaux-Arts evaluation criteria such as symmetry around multiple axes were no longer used in assessment of student work. The inscrutible character of design and design teaching remained, however, and two movements in the 1960's sought to modify what was seen as an excessive tendency in designers to become attached to formal images.

One group, of which Christopher Alexander was a prime mover, proposed by the application of mathematical models to relieve the designer's dependence on intuition alone for making design decisions; as Alexander's book, Notes on the Synthesis of Form explained in the introduction, "The Need for Rationality":

> The modern designer relies more and more on his position as an "artist," on catchwords, personal idiom, and intuition - for all these relieve him of some of the burden of decision, and make his cognitive problems managable. Driven on his own resources, unable to cope with the complicated information he is supposed to organize, he hides his incompetence in a frenzy of artistic individuality. As his capacity to invent clearly conceived, well-fitting forms is exhausted further, the emphasis on intuition and individuality only grows wilder.[41]

Alexander proposed to improve this situation by formulating a hierarchical breakdown of the functional aspects of problems into smaller and smaller components, identifying interrelated attributes and criteria which formed the "explicit map of the problem's structure." The idea was that one large complex problem could be decomposed into many simple relationships; solving on the basis of the elementary problems would sum eventually to the solution of the whole.

Impetus for the second group, which evolved from sociological concerns, came from urban unrest and social awareness movements of the mid-1960's. The architect's elitist role and preoccupation with middle-class values led to the formation of anti-architecture groups which attempted to assert the concerns of the poor and other minority groups. In a less militant vein, serious efforts were begun to find ways of involving users of architecture in the design of the environment. In the 1970's both the mathematicians and the sociologists have shifted to a consideration of the complex interactions of human behavior, the environment, and socio-political issues in architecture. Thus far, no model powerful enough to supercede the accepted way of design teaching has emerged; much that transpires in architectural studios in the 1970's is in the tradition of the Royal Academy classes of 1680.

In charting the changes in mechanical engineering and architectural instruction at MIT, one is tracing the development of pioneering curricula in each field: the Department of Architecture offered the first collegiate program in architecture in the English-speaking world, and the Department of Mechanical Engineering was part of the first American engineering school with specialized instruction in various facets of engineering: civil, mechanical, chemical, and mining. In many ways, the characteristics of these two curricula typify the general development of collegiate instruction already outlined.

Mechanical engineering

In accordance with the philosophy of the Institute's founder, William Barton Rogers, the original curriculum in mechanical engineering was both theoretical and practical. All students, regardless of specialization, studied the same subjects in the first two years: mathematics, drawing, physics, chemistry, English, foreign language. Only five courses in the final two years of the 1866-67 curriculum are peculiar to mechanical engineering: applied mechanics, machine drawing, machines and motors, heat, and materials. The 1876-77 Catalog course description explained the instruction given:

> Subjects, not text-books, form the basis of this course of instruction. But the best text-books and engineering publications are freely consulted and carefully studied. The department has a valuable Technical Library for the use of students. Two classes of lectures are carried on simultaneously. In one class the Mathematical, and in the other the Practical aspects of the subject are considered. Weekly excursions are made, through the courtesy of the managers, to establishments where machinery is manufactured, or where it is in operation. The gentlemen in charge often explain to the students the interesting operations which they are directing.[42]

By 1881-82, the original five mechanical engineering courses had been added to and rearranged into a curricular pattern that remained fairly stable for the next thirty years. The first year was devoted wholly to fundamental courses in English, history, mathematics, chemistry, drawing, and foreign language required of almost all students in the Institute. In the second year, specialization began with courses in mechanics, applied mechanics, shopwork (carpentry and forging) and machine drawing added to classes in humanities, mathematics, and physics. Engineering subjects expanded further in the third year: applied mechanics was joined by subjects in thermodynamics, steam engineering, machine drawing, foundry work, surveying, and machine design, while physics, humanities, mathematics, and foreign language continued as general subjects. By the fourth year, the curriculum was composed almost entirely of engineering classes: applied mechanics, materials, engineering laboratory, hydraulics, machine tool shop, machine design, professional subjects, and thesis. From 1886 onwards, the fourth year provided limited time for one of several options; at various times, marine engineering, locomotive construction, mill engineering, naval architecture, and heating and ventilation were available as two semester specializations. Such options were the only electives provided in the four year sequence.

Modifications to the program were made shortly after 1911; engineering subjects added to the third and fourth years included heat engineering (replacing steam engineering), electrical engineering, materials testing laboratory, and an additional semester of machine design. Additional options, such as engine design, became available as entire fourth year specializations, rather than single two-semester subjects as before. Limited choice electives also found their way into the final year. The next major curriculum shift occurred after 1956-57, when a new structure for the sequence, dividing work between General Institute Requirements and the Departmental Program brought more flexibility (through increased elective time) to the course of study. All required courses in drawing and shop work - wood, metal, and machine tools - disappeared, and design subjects diminished to two. Though some subject names have changed since then, the 1961 required curriculum is essentially the same as that listed for 1974-75.

How was design incorporated in the curriculum? Evidence about the nineteenth century subjects is extremely scanty since the catalogs list neither text book (if any existed) nor subject description. From the 1906-07 Catalog onwards, subject descriptions exist which give some idea of the instructional content. Many of the theoretical subjects provided information, principles, and procedures necessary for the design of machinery, and towards that end, they included some design exercises in their work. In the 1906-07 Catalog, one finds the following descriptions:

> 360. MECHANISM.
> This course consists of 90 lectures and recitations during the first and second terms of the second year. It includes a systematic study, not only of the motions and forms of the various mechanisms occurring in machines, and the manner of supporting and guiding the parts, independently of their strength, but also of the design of gear-teeth, and the study of mechanisms found in modern American machine tools, and in cotton machinery. The course also includes the theory and practice of designing valve-gears for steam engines, including the plain slide valve, link motions, radial valve-gears, double valves, and drop cut-off valves.[43]
>
> 401. DYNAMICS OF MACHINES.
> A course of lectures and recitations given three hours a week for nine weeks in the first term. The courses in Dynamics of Machines include a number of the principal applications of Dynamics to moving machinery, such as governors, fly-wheels, the action of the reciprocating parts of the steam engine, etc. The various subjects are treated in such a manner that the results are suitable for practical use in designing, and also in making experimental investigations.[44]

The principal design subject was, however, machine design:

> 404. MACHINE DESIGN.
> To this work are devoted, including all time used for lectures, calculations, and drawings, nine hours per week during the first term of the fourth year. The main object of the course is the application of principles already learned to the solution of problems in design. Each student makes a number of complete designs, such as a boiler, a large shaft with pulleys and gears, a set of couplings, etc. For each design the constructive details are carefully discussed; each student then makes all the necessary calculations to determine the dimensions of every part, not by the use of empirical formulae, but by means of principles already acquired, and finally he completes the working drawings. The scope of the designs is such as to include most of the elementary principles of design, and yet is sufficiently limited to enable the student to complete every detail, as it is believed that only by such thorough work can real benefit be obtained.[45]

From this description and from examination of textbooks on the subject, machine design appears to have concentrated on mechanical configurations and the proper sizing of parts. Integrative work, as advocated a decade later by the Mann Report, is not evident from the information here.

With options available in the mechanical engineering curriculum after 1920, additional subjects for design work were created. As with machine design, they focused on specific topics:

> 2.58 POWER PLANT DESIGN
> From a given load curve and from a chart showing the demands for steam used for industrial purposes a complete assembly drawing of a power house is made, the assembly drawing being in sufficient detail to enable one to construct working drawings from it. The work consists largely of calculations combined with drawing room work. The cost of the plant is estimated as is also the cost of operation.[46]

Machine design continued until the end of the 1950's to be the major design subject for mechanical engineers, remaining focused on the technical contexts of design. The political and social events affecting design education in the 1960's brought changes to engineering education as well: social responsibility and "relevant" engineering, along with a recognition of the need for integration of humanities and social science subjects with the technical curriculum, altered engineering design work. New kinds of projects, often around interdisciplinary topics, brought the student into contact with real problems in actual situations; reality was also incorporated through cooperative projects with industry, giving students the opportunity to design devices within the constraints of manufacturing and marketing practices. The mechanical engineering class studies had elements of both kinds of reality simulation: students worked on a "live" problem based on a demonstrated need, and within the department were resources to continue the student's work beyond the semester if desired. Development, testing, and even marketing of a product based on the semester's preliminary design were possibilities available to the class.

Architecture

The architecture curriculum, like mechanical engineering, began as a theoretical and practical course in the Department of Architecture and Building, as announced in the first Institute Catalog (1865):

> The courses of study will be extensive and thorough; but their object will be to furnish the instruction and discipline that cannot be obtained elsewhere, rather than to cover the whole ground of architectural study. Much of the ordinary detail of work must necessarily be left for the students to acquire in architects' offices. The course will, however, be practical, as well as theoretical; and

> will embrace the scientific study of construction and materials, in connection with the courses of Civil Engineering, as well as that of composition and design, and of the history of art. It will consist chiefly of a series of projects or problems, in Construction and in Design, to be worked out by the student. These will be illustrated by lectures upon the theory and practice of the art, pertinent to the subject in hand.[47]

Actual instruction in architecture did not begin until 1868, however, when William Robert Ware, an architect who first headed the Department, returned from a trip to Europe with sufficient books, papers, photographs, plaster casts, architectural drawings, and other materials to serve as the basis of instruction. Owing to the instructional requirements of subjects in history, general cultural studies, science, and construction, sufficient time in the curriculum for design work was at first not available. Design began its ascendency in the curriculum in 1871, when Ware invited Eugene Letang, graduate of the Ecole des Beaux-Arts in Paris, to teach the classes in design; the 1871-72 Catalog advised students that

> in addition to the exercises which directly accompany and illustrate this instruction, a series of independent exercises in original design, consisting of problems in architecture and ornament, will be given out from time to time to students who are sufficiently advanced in their studies to take part in them with profit. No student can receive the Diploma in Architecture, unless, besides persuing the regular studies of the third and fourth years, he has presented a proper number of such original designs of a suitable degree of merit. As these studies leave but little time for preparing these works, it will be necessary for most students either to take time for them after other studies are finished, or to extend all their work over a longer period.[48]

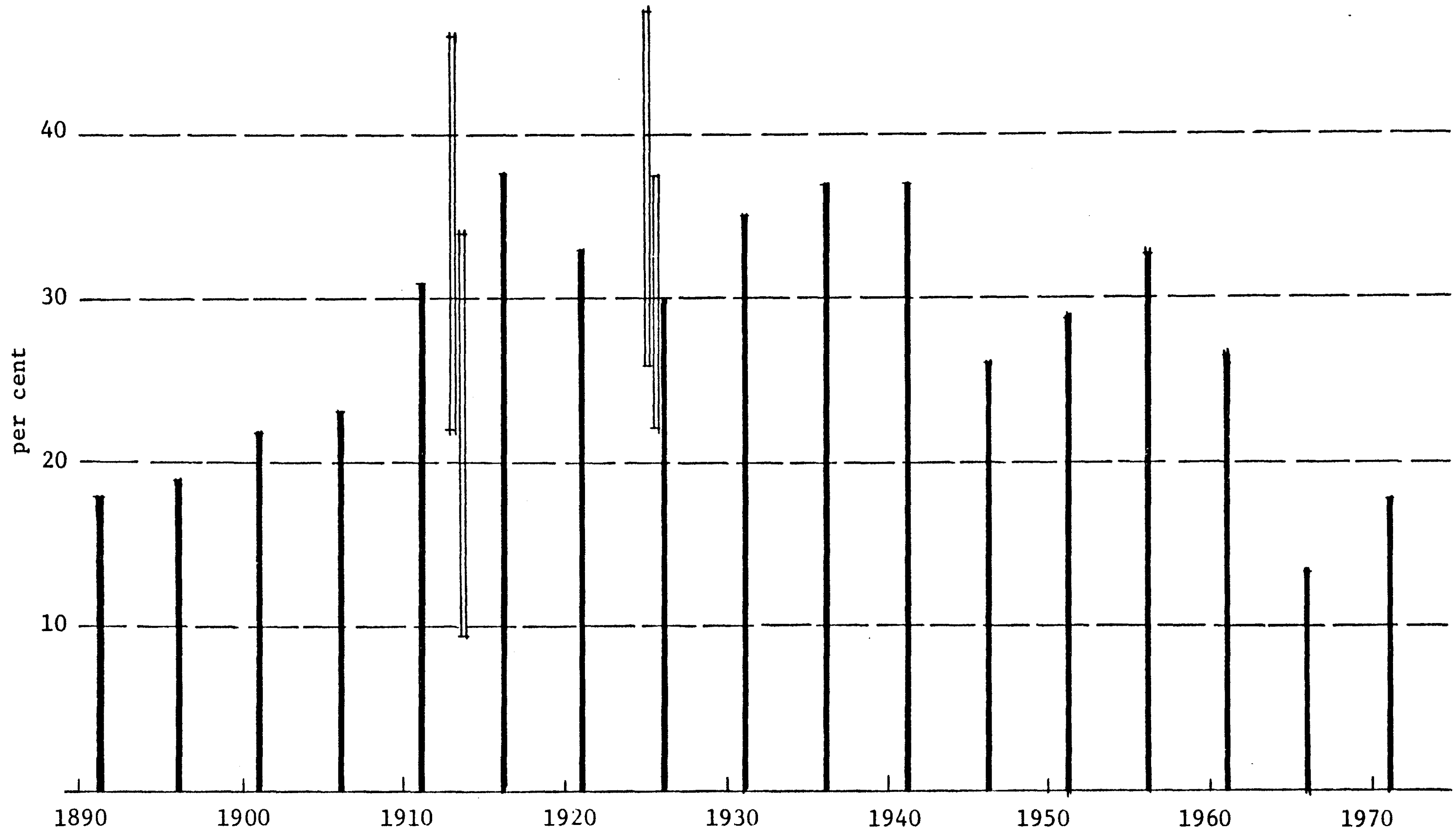
"Original design" soon became a regular part of the curriculum; by 1876-77 the catalog could report that "during the third and fourth years the students are constantly practiced in original design, the character of the problems given out and the time allowed for their completion varying according to the advancement of the class and the kind of drawings required."[49] The Department of Architecture and Building became just the Department of Architecture in 1886; by 1891, curriculum patterns which remained fairly constant for the next half-century were established. The first year gradually evolved away from the common program established for other departments at the Institute as architectural drawing, then history, was permitted in place of chemistry; the second year began the design sequence, continued history and rendering, and added various building technology subjects.

> DESIGN I.
>
> A course of five hours per week in the first term and ten in the second term of the second year. This course lays the foundation for the aesthetic training of the student. He is made to study and analyze the elements of the best examples of Classical Architecture, in order to cultivate his taste and sense of proportion. The fundamental principles of Architecture are inculcated, and the influences governing design are explained and discussed. By means of problems in design the student is taught the methods of study, the principles of academic rendering, and obtains the necessary training of the hand and eye. The course is given by means of individual instruction in the class-room, and by criticism of the students' work before the class.[50]

By the third year, mathematics and physics classes were completed and the student's time was devoted even more closely to professional work in architectural history, practice, technology, and design; these studies continued through the fourth year when design work was concluded by a thesis presentation of an original design. In 1927, a fifth year was added to the undergraduate program, extending the work in design yet another year and giving additional time for studio art - either painting or sculpture. The curriculum in architecture had become so distinct from the work of the rest of MIT that in 1916, when the Institute moved to its present location in Cambridge, the Architecture Department remained in Boston. It did not rejoin the other departments across the Charles until 1938. During this time, there was a steady increase in the percentage of the curriculum time devoted to design studio; it rose from about 18% of the four year course in 1891 to a peak of 37% in 1916 and again in 1941. This development was paralleled by increases in studio time at other architectural schools, as the ACSA statistics on design time in 1913 and in 1925 show. (See graph on the next page.) It was observed that

> the carefully prepared curriculum laid out by Mr. Ware and his advisors had slowly changed from a well-balanced schedule of theoretical and practical training to one in which the design course took almost all of the student's time, and where the technical and practical courses were reduced to a minimum. This was partly brought about by changes in the French School (the Ecole des Beaux-Arts), where more and more stress was being placed on theoretical design, but it was largely due to a misconception of the teaching in France by many Americans.[51]

Significant changes in the curriculum came in 1944 with the appointment of William Wilson Wurster, a progressive architect open to the influences of modern design in Europe, as Dean of the School of Architecture and Planning. By 1946-47, the percentage of time devoted to design studio had been reduced to 27%, and a course in basic design preceeded the study of architectural design. Architectural history was substantially reduced, becoming part of a subject in western art and civilization, and work in structures and building technology was stressed. For the first time since 1896, the freshman year was for architects the same as for all others in the Institute. Although the department's program diverged



DESIGN STUDIO AS A PERCENTAGE OF TOTAL CURRICULUM
CREDIT IN THE ARCHITECTURAL PROGRAM AT M.I.T. 1890-1970

Range of responses from
ACSA surveys
ACSA schools
non-ACSA schools

from the common first year during the 1950's, the institution of General Institute Requirements in 1961 returned to the program the scientific base from whence it had departed almost a century earlier. The most recent curriculum shift came in 1966, when in response to the need for more liberal education for architects, the professional program in architecture was raised to the graduate level. Undergraduate study now comprises four years, leading to the Bachelor of Science degree; a student intending to continue in the professional program in graduate school will now spend about 18% of his undergraduate academic time in design.

Despite the vastly increased emphasis placed on design in architecture in comparison to design in mechanical engineering, a certain narrowness of scope characterized architecture's design instruction as well until the Second World War. As in the case of engineering, changes in society brought about the reconsideration of traditional attitudes and definitions of problems. From the first, architectural design problems were generally marked by an absence of context, site, client, and in some cases, perceived need; "A Design for a Country Depot Employing Wood, Iron, Brick, and Stone" (1871) could have existed anywhere its Gothic quaintness would be tolerated, just as "A Concert Hall" (1930) would have been at home on any treeless plain where no other structures could be mirrored in its reflecting pool. Only in 1944 does building design begin to show interest in a particular place, and not until the mid-1960's was there concern for the program and the users of the thing designed. Along with commitment to the investigation of alternate roles for architects in society, this concern for users forms a dominant characteristic of the design faculty at present. Through all the changes, however, the method of teaching design has remained remarkably constant: a teacher working individually with a class, setting the problem to be considered and criticizing the designs produced.

IV.

INTRODUCTION TO DESIGN

> Introduction to the design process in engineering, stressing the creative approach. Problem definition and concept generation, visual thinking and graphic communication, design analysis and optimization. Familiarization with standard machine elements, design specifications, production techniques and economic considerations. Instruction via case, project and independent resource methods to simulate professional engineering practice.

"Introduction to Design" was a one semester undergraduate subject in mechanical engineering at MIT which was studied to learn about the practice of teaching design in engineering. The class met twice a week for hour lectures, and once each week for a three hour design laboratory; four additional hours per week were expected of the students to be spent in preparation for the class. MIT's undergraduate program in mechanical engineering attempts to provide sufficient alternatives to meet a variety of student interests. According to the catalog,

> In particular, the Department recognizes in its specification of curricula requirements and in its subject offerings three categories of students it wishes to serve: 1) those who will base their professional engineers on the Bachelor's degree with no further formal study; 2) those who will proceed to formal graduate study, in mechanical engineering or in an allied field; and 3) those for whom the undergraduate program in mechanical engineering will provide a broad base - a base of intellectual style as well as intellectual content - for further professional study directed toward medicine, law,

business, or industrial management.[52]

The undergraduate curriculum of which "Introduction to Design" is a part is composed of four components: general humanities, science, and social science subjects required of students in all departments (40%); the required departmental program (38%); restricted electives (6%); and unrestricted electives (16%). "Introduction to Design" is the first of two design courses required in the departmental program. While the subject has no listed prerequisites and may be taken by freshmen in the fall semester, it is generally helpful for students to have had or be taking concurrently the first course in solid mechanics; about two-thirds of the class come with such a background.

"Introduction to Design" was taught by three faculty, all mechanical engineers, who shared responsibility for the lectures and lab sections. The youngest of the trio, Professor Allen, served as overall coordinator and taught 2 lab sections; he and Professor Baker presented most of the lectures. Professor Child, the most senior faculty member, was primarily responsible for a design laboratory section.

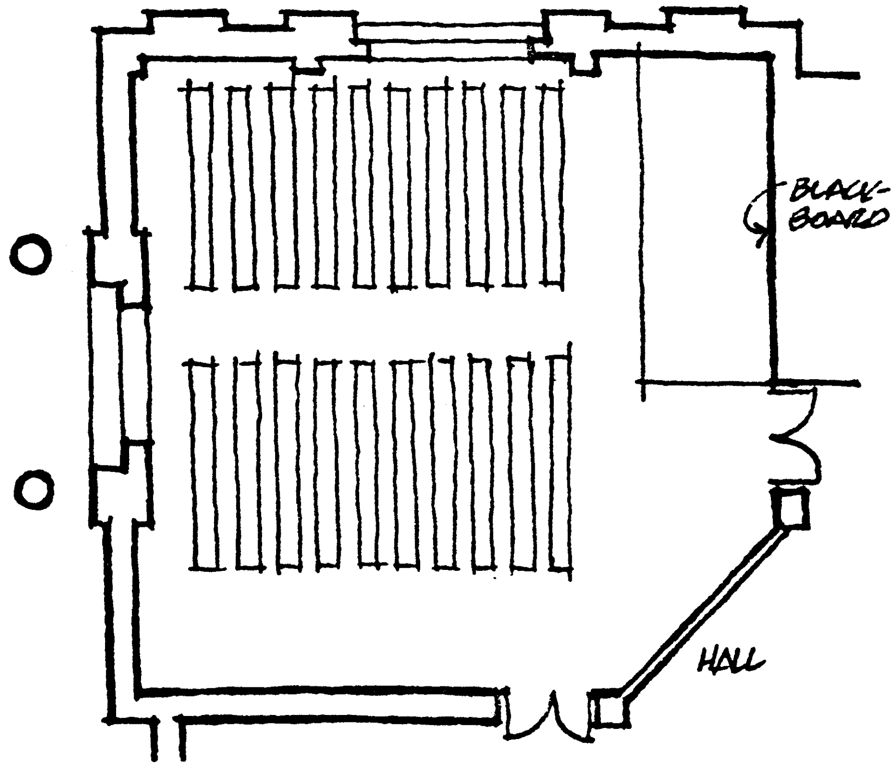
The students, most of whom were sophomores in mechanical engineering, numbered about 55. To judge from the smaller sample interviewed from one of the laboratory sections, most had chosen engineering because of their interests in mathematics and science and had selected mechanical engineering because it was perceived as the most general of the engineering disciplines.

> I flunked out of economics and ended up in mechanical engineering. I'm good in math and interested in how things work.
>
> It's something I like to do - it fascinates me.
>
> When I was in high school, I was interested in math and science from the needs of my (developing) country. Mechanical engineering gives me more ways to go and involves enough math and science that I can be pleased with it.

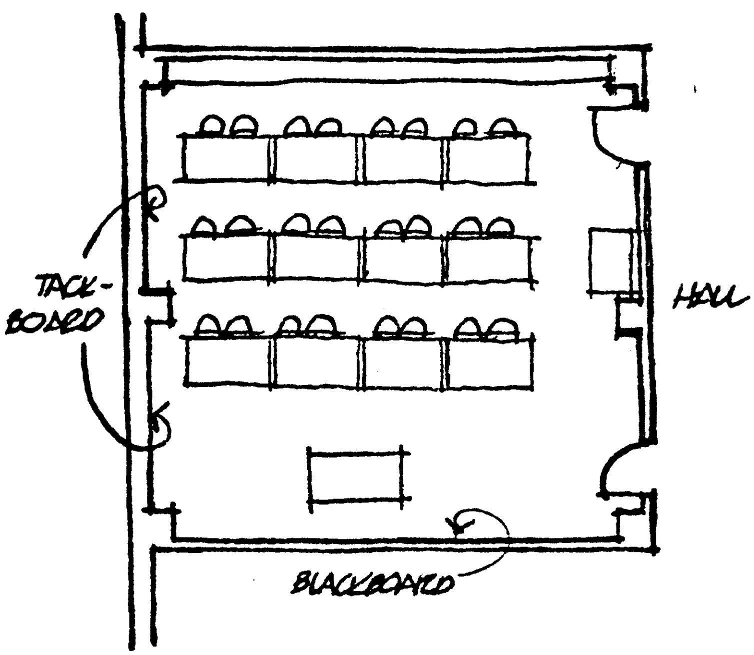
None specifically mentioned an intended career as a mechanical engineering designer, but special interests in biomedical engineering, patent law, and research or teaching were identified by those interviewed.

The class met on Tuesdays and Thursdays at noon for hour-long lectures, then was divided into four groups of approximately twelve to fifteen students for design laboratory sections, which met twice a week on Tuesday, Wednesday or Thursday afternoons from 2 until 5. Lectures were held in a two hundred seat classroom with fixed auditorium-type seats, two tables on a raised platform in the front, and chalkboards extending across the front wall. A projection screen could be lowered as required. The design labs met in smaller classrooms equipped with twelve flat-topped tables which contained drawing boards and drafting machines underneath. Storage cabinets extended along the back wall; a flat plan file and defunct machine occupied the side wall, and a chalk board hung across the front. (See sketch)

Instruction in this class was based around two design projects, each lasting half a semester. While the design projects were worked on during the lab sessions, lectures were so arranged as to provide the supplemental



LECTURE ROOM



DESIGN LABORATORY

information needed for design. Thus, for the first project, a device not to exceed certain dimensions which would travel down and back on a given track under power obtained by changing the vehicle's center of gravity, all to be constructed from a kit of miscellaneous materials, accompanying lectures dealt with the ability to visualize, to sketch, and to construct engineering drawings. For the second project, the design of a front wheel disc brake for a bicycle, lectures were concerned with disc brakes, forces on materials, kinematics, and engineering design components like fasteners, cams, constant force springs, and snap rings. (A schedule of the semester, together with the original project statements, can be found in Appendix B.)

The first class meeting set the tone for the semester as well as providing an overview of what the students might expect. Handouts describing the schedule for the first half of the semester, and the names, office locations, and phone numbers of the faculty involved, and the basis for grading were distributed at the door, and in an almost conversational tone, Professor Allen introduced himself and began. Students were advised to budget the time they spent on the course since experience showed that many found it to be time consuming.

> We try to keep it to 9 hours credit. For the first project, we suggest you budget 50 hours and for the second project, 40 hours to avoid the last minute rush. You will learn that design takes a hell of a lot of time.

The textbook for the course, <u>Introduction to Engineering Design and</u>

Graphics by Beakley and Chilton, was recommended, not required.

> We keep looking for the Great Design Book in the sky. This is as close as we have come. It is a good book - I'm not sure that it is good for MIT, but we'll give it a try. ... The first part talks about design and is fairly editorial, but you have no idea of what design is about, it is good.

A suggested reading assignment was given on the board. Students were told where they might go to obtain handouts they missed getting in class, but they were also counseled to attend class regularly "since there will be something to do almost every time. We find this keeps your attention - no one goes to sleep." The other two lab instructors were introduced, and lab assignments were made on the basis of available time in the individual's schedule. The availability of design awards (cash prizes) and opportunities to get financing for development of student designs were summarized: "You might even get your tuition back if you are careful." It was then explained that

> (this class) is probably different from other engineering courses. It is more of an apprenticeship than a regular course. You must work with your instructor very closely and come to class. Design work is amorphous and there are no unique answers. This is unsettling to many since it is unlike what school makes you used to. You will have a chance to fail - not academically, of course - with a minimum cost. Your instructor will judge you far less severely than will outside funders. You should be careful; design work can be very time-consuming, so pace yourself. ...Some of you will like to more than others; design is perhaps more an art than a science. But give it a try - even if you find you don't like it, you should recognize design ability in others. ...Design is in demand now. The Holloman Report, a blue-ribbon commission which recently finished studying engineering education, says there should be more design taught to engineers. Too many things today are poorly designed; I get frustrated at least once a day by things that just are not designed.

After a comment on the increasing scarcity of materials, there was additional description of the class.

> You will do two sort of classical design problems. In the lectures, we will try to make you think more like a designer, to be happier with many alternatives. Also, we will try to make you better visual thinkers. It was said that Tesla, the great designer, could build a giant turbine, run it for a few years, then disassemble it and see where it was worn - all in his head. ...We will focus on visual means that enable you to communicate to others and talk back to yourself, then on the way you get things to a machinist for a part to be made. In the second half of the semester, we will talk about standard components and reference material related to the second project - chains, sprockets, bearings, joints, gears. The actual project for the second half is not yet decided - we welcome any suggestions from you. About the lab projects: the first one is a microcosm of engineering, with fictitious constraints, precise specifications for the product, and exact timetables for you to do the best you can with. The second will be a "paper" design of a product in a way that will work. You will be asked there to apply what you have learned from this class and other experience.

This introduction to the class established several characteristics of the lectures. Instruction by the principal teachers was informal, often humorous, and open to interruption by questions from the floor. Duplicated material in the form of handouts was provided at the beginning of many lecture periods; this ranged from blank sheets of paper for use in class drawing exercises to technical information from books and manufacturer's design handbooks for specific machine components. In the course of the semester, over 70 pages of design information plus about 30 sheets of or for drawing exercises were distributed to class members at lectures.

Design laboratory periods were more diverse in their structure. All shared the characteristic of being student work periods; group presentations or discussions which occurred there were outgrowths of problems being experienced by a number of students in the lab, not as a result of left-over material from the lectures. The design stages which students were expected to complete were specified on the weekly schedule, a pace that was with few exceptions maintained. For example, in the case of the first project, the "Potential Racer" design, the lab period began with one hour explanation and discussion of the constraints and details regarding the racers, followed by a ninety minute period when students were left to generate 5 design concepts and sketch them on paper. Students were free during this time to talk among themselves and they generally did; the instructor (a graduate student filling in that day for Professor Baker) provided some intermittant discussion on fusees (variable diameter spindles), the importance of minimizing the vehicle's dead weight and maximizing the change in altitude of the center of gravity, and the relationship of torque to the drive wheel.

In the following week, the kits of materials were distributed, an introductory tour of the shop was given, and more specific comments about the physical factors affecting the designs - air resistance, rolling friction, traction, and bearing friction - were examined. After this - the conceptual sketches from the previous week were returned to the students, who were now asked to narrow down their thinking to one preferred concept. (An evaluation procedure, which identified salient characteristics of the designs - speed, reliability, ease of construction, elegance, and simplicity - and gave numerical ratings to each, had been presented in lecture; I observed no one going through the formal process.) About a half-hour of lab time, with the instructor out of the room, was allocated to this activity. The students occupied themselves in various ways: 5 chattered with one another over the various pieces of the kits; two played with the materials quietly by themselves; three drew on the designs returned to them; and one student stared for a long time at the ceiling, then commenced working. When the instructor returned to consult individually with students about their designs, no one was particularly eager to see him. When he made it clear that designs did not have to be final in all particulars, he found some students ready for help.

The student practice of not working during laboratory time continued through the semester, even though they were frequently given the opportunity to work on their designs or consider a particular assignment posed by the instructor. Completion of these class-assigned tasks was invariably deferred until the next class period or the end of the week; the students were not required to finish classwork by the end of that day's class. Design laboratory time was utilized by many in the class as a period for consultation with the instructor about work brought in, and most of these students preferred to leave after their particular problem had been aired. The class tended not to last until the lab period was officially over at 5:00 p.m.

A preponderance of design consultation time both on this day and in general was devoted to the explanation or clarification of physical realities affecting the design. For students in the lab who had completed neither the physics nor elementary mechanics subjects, these explanations were necessary instruction about such things as free-body diagrams, graphs of velocity/acceleration/distance/time relationships, the factors which affect traction and friction, and the like. But even for students who had taken these subjects, reminders of their appropriateness to or impact on the design issues at hand were necessary when the students failed to apply the principles learned. Consultations thus focused extensively on physical realities, either with leading questions left unanswered ("Think about that") or outright explanations of physical principles; the instructor's cries "Have you forgotten everything from 2.01? (the mechanics course)" or "Don't they teach you these things in 2.01 anymore?" were uttered more than once in almost every lab period. When uncertainty about physical behavior seemed widespread, the principle (or problem) would be posed to the class at large, illustrated with drawings and equations on the chalkboard as appropriate.

Individual consultations tended to be brief, seldom lasting more than five to ten minutes. The instructor rarely initiated proposals; rather he listened to the student's description of the problem and reacted to the work he was shown. Areas he perceived in the design as being doubtful, but about which the student had not raised questions, might be broadly hinted at without suggesting specific changes. Thus, one consultation concluded with: "In concept, it's pretty good. In execution, it is somewhat open to doubt." It was left to the student to identify the doubtful aspects. On specific matters which the student admitted were causing him difficulty, however, the instructor would go to considerable lengths to assist in clarifying the problem; explanations of principles, sketches of possible mechanisms or configurations, equations to solve for unknown forces, diagrams of force resolutions, all might be employed to explain with sufficient detail the possible resolution of the dilemma.

> With one student, who after an hour and a half of working time had produced no additional sketches towards a final concept, there was nothing new to consult around except the student's general question about a pendulum drive for the vehicle as shown in one of his conceptual drawings. The instructor suggested a scheme whereby the pendulum would drop, disconnect from the wheels, then reconnect when the track run was completed and rise again under energy from the vehicle. When asked if he understood this conceptually, the student replied that he did, but he did not see how the mechanism which might accomplish this could work. The instructor then sketched one schematic way this might be accomplished; the student remained unsure of the operating characteristics, and another drawing, in greater detail, was made which realized in concrete terms the schematic drawing. The suitability of a pendulum drive for the racer was not discussed.

Evaluations of the student's designs were handled differently for the two projects of the term. For the racers, which were both designed and built, the obvious means for testing was to have a race. A single elimination contest was held, with preliminary heats run during one lecture period and the final rounds concluded in the next lecture meeting. Observed by a crowded room of cheering or groaning spectators (according to the racer's performance) and cameras from the campus press, the "potentially Great Race" had a decidedly carnival-like atmosphere. Actual grading of the projects, however, was somewhat independent of the outcome of the contest outcomes; lab instructors reviewed the racers on the basis of the concept behind the design, the progress (learning) evidenced by the individual as he worked on the design, his diligence, and craftsmanship in construction, as well as the racer's performance under trial. Some feedback from this evaluation was given to students later in the term. The procedure for evaluation of the bicycle brake designs was much less a public event; because the designs were completed at the virtual end of term, there was no time for presentation of the individual designs. Instead, five designs selected by the instructors as being representative of the major classes of solutions were briefly explained by their authors to the class and several invited experts during the last class meeting. Graded drawings were available to the class for pickup during the exam period; if individuals wished to discuss their finished products with the professor there was a private arrangement between the two parties. Final grades in the subject, as announced at the beginning of the term, were determined. 30% by the first project, 30% by the second project, 30% by participation in laboratory and other assignments from class, with 10% being reserved for the instructor's leverage.

In a number of ways, "Introduction to Design" fits the paradigm of design instruction in engineering which considers analytic and synthetic aspects of a given subject together. The lectures here were so arranged and the problems so selected that the factual matter and analytic processes necessary for design activity were provided for the student; additional theoretical explanations were also given in the lab periods. Vestigal remains of machine design subjects, of which this class is a direct descendent, can be found in certain lectures towards the end of the term (those concerning transmissions, chain drives, and the like), lectures which had little to do with the problem at hand but which were included anyway because, as one instructor put it, mechanical engineering designers will need to know about these things and they just aren't covered anywhere else in the curriculum.

The format of the course has evolved over the past several years into a pattern centered two projects: one, a device to be constructed from a given set of materials to perform in a stated manner (previous examples: the "water waiter" race involving vehicles that carried a plastic airline-type drinking glass full of water without spilling; the "water gater" contest for devices, powered by the descent of a bag of water, which ran along a string and released a marble into a trough below), and the other, a design drawn on paper according to standard engineering practice, including parts and assembly drawings, with specifications for materials, dimensions, tolerances, and finishes along with design calculations (previous example: a windmill). "Introduction to Design" has been taught during this time by a team of professors, all members of the systems and design faculty in mechanical engineering, who collaborate on the selection and teaching of problems in the class.

Projects related to the first type are utilized elsewhere as design exercises for engineers. Student lore reports of projects at Berkeley to build a glider device that would said the maximum distance down long straight corridors and to construct devices which would permit raw eggs to be dropped one or two floors onto concrete without breaking. There was even a national competition, sponsored by the student chapters of the American Society of Mechanical Engineers, for racers powered by an ordinary mousetrap. Horizontal surfaces (other than desks) in the design lab room were covered with remains from past contests of this class; outstanding or unusual devices from recent contests were displayed in glass front cabinets on the ground floor. Projects of the second type, which are far more closely linked to real-world design problems, bear some relationship to the nationwide SCORE (Student Competition on Relevant Engineering) design program, although the scope of projects given to the class are necessarily more limited.

For both projects, however, the process of design followed the same models; because design work was seen but once a week and time allowed for the project was limited, a scheduled pace was maintained in lab. Introduction of the project, consisting of a duplicated copy of the problem, specific requirements, presentation format, and deadline(s), was followed by a discussion in the lab of the "salient features" of the thing to be designed. In the case of the racer, this involved a discussion of the center of gravity change, mass and acceleration, torque and drive wheels, friction, traction, and bearings; in the case of the bicycle brake, there was a work session and discussion (after much prodding from the instructor) on the mechanics of braking, limiting the torques on the disc, the increased forces and torques on the wheel and fork, and the energy dissipated in the disc brake under the worst conditions, and the contact force requirements on the brake pads. (The brake was to be capable of stopping the bicycle from 15 mph in 15 feet, under wet or dry conditions.) Without assistance from the instructor, it is doubtful if many in the class would have developed a sufficiently accurate understanding of these factors to undertake a realistic design, since he ended up answering most of the questions posed for general consideration.

Once the preliminary analysis of the situation was completed, students were left to evolve their own design concepts; the schedule allowed a week for this activity. In the brake project, students were told to "sketch out one or more concepts which might satisfy the factors (just discussed in analyzing the problem.) Think also about the parameters of people and bicycles." After conceptual design was completed, the process of resolving details and sizing component pieces was carried on almost simultaneously with the production of drawings. Consultations during this time frequently questioned the amount of material being shown in scale drawings: "You could build half the bicycles out of the metal in this brake." Or "Your disc and brake pieces are thick enough to stop a Mack truck."

One typical consultation session began with the student explaining the present state of his drawings; Professor Baker asked for some clarification:

Professor: Why don't you sketch a superficial view from this direction *(points)* for me?

The student does this.

Professor: I'm still not following the following things...(explains and indicates his misunderstanding). The cable is pulling here? Is it pushing or pulling the wedge? (Student responds) This whole thing is on a track? (Student responds) Well, I'm beginning to see that it will work. The question is, why are you going to all this trouble to get motion up here? Wouldn't you be better off, instead of putting in a second fin, why not take this...*(sketches and concludes comment.)* Why not put another two pads here? Right now you are doubling or tripling the material you will need. The mechanism looks extremely complicated - I have grave doubts that the entire thing would work together.

Student: Why?

Professor: *(Explains the difficulties he sees.)* What I'm saying is that these are not self-adjusting - only one set would ever work at one time. *(Re-explains his point and indicates the difficulty in the drawings.)* If there is any kind of uneven wear, only one pad will effectively operate. The problem with this design is that it is trying to put in two working parts to save on the torque, and you are losing in design. My main complaint ... is that there is no adjustment for uneven wear (on the pads). Get rid of this complicated mechanism - one actuating mechanism is far more efficient.

As identified by the instructors, five different classes of design solutions emerged from the class: mechanical linkage, hydraulic, cam, servo-assisted, and a unique "bristle brake"; one design from each of these five categories was selected for presentation (via projected transparencies) to the class at its final meeting of the semester. Questions raised at this public review were, as in the consultation sessions in lab, primarily concerned with the operational characteristics of the brake under scrutiny:

What is the clearance for the spokes?

What is the load on the passive caliper? Can it be adjusted?

Will this piece cause rotation around the brake?

Could you use quick-release hubs with this design?

How do you activate the braking system?

Is your master cylinder large enough?

Is there some advantage to the geometry of the brake handle going through 90 degrees?

What kind of pad forces are you talking about?

What is the heat gain in braking?

These queries could not always be answered to the satisfaction of the questioner.

Present at this session were guests invited by the instructors, two professors from the campus innovations center and one professor who had also designed a disc brake. It was from these gentlemen that the major judgemental came; in summary remarks one concluded that "the first three (presentations) are conventional approaches and very good designs. ...the last one (the unique bristle brake) shows a very good thought process, but it is a drum brake, not a disc anymore." He went on to assert that the dissipation of heat gained in the braking process would render the brake useless since the plastic material specified in the design was not adequate for the task. "That plastic will only last you two minutes."

Any further evaluation was a private matter between the instructor and the student. In thus introducing design through this class, the main instructor hoped "that the students would develop a little more respect for design and have some sense, be more aware, of design as an issue, being something they come into contact with and something they have to do (professionally as engineers)." He pointed out that this was not the only class in which design was done: of the nine subjects required in the undergraduate departmental program, all but one include some elements of design in relation to the subject matter under consideration. (In addition, the bachelor's thesis usually involves design.)

He finds the evaluation of design work "incredibly subjective." Generally, he rates each student's project according to the design idea, its execution, and the project planning ability evidenced by the student in carrying it out. (When he has had students rate themselves along these three categories, he finds their judgements of their work harsher than his, but in the main, they agree.) In addition, though, he gives credit for "diligence, effort, and sheer hard work; ingenuity, workability and realistic feasibility."

Against the perennial student complaint that "Introduction to Design" takes more time than the credit allowed, Professor Allen defends the scope and number of projects assigned. (Formerly three projects were given.) "If we give them (the students) something so simple that it is easily done, they will be bored stiff." Increased credit for the subject is not presently possible in the context of the curriculum; "we have to justify the present (credit) level." Design teaching in the subject is as it is "for lack of a better way; the students learn a lot about design by having the supervised opportunity to do it."

V.

ARCHITECTURAL DESIGN - LEVEL ONE

> This studio is intended as the first architectural design studio for its enrollees; it has no formal prerequisites.... The primary objective of the studio will be to obtain perspective on the issues involved in residential design both at the neighborhood level and in the individual dwelling unit. A secondary but important objective will be to practice analytical problem-identification-and-solving procedures and skills in graphic representation that are essential to all architectural intervention.

"Architectural Design - Level One" was a one semester beginning studio at MIT which was studied to learn more about the practice of teaching design in architecture. The class met for three hours, three times a week, and students were expected to devote another eleven hours per week to individual work on studio projects.

The department of architecture in which this studio was taught describes its undergraduate course as "a flexible program" which allows students to "develop individual courses of study best suited to their needs and interests." The philosophy of the department is stated by the Catalog:

> The Department of Architecture takes as its fundamental charge education for change in the relationships between people and their environment. Faculty and students share concerns for the quality, character, and nature of the visual and physical surroundings on intimate and large

> scales. They express a commanality of commitment to understanding ways in which people conceptualize the built and natural environment and their roles in making and using that environment. Undergraduate and graduate students work closely with each other and with the faculty....Education in theoretical and practical modes among a diversity of attitudes and media enriches a student's experience in the Department and proposes a variety of alternatives for career paths.[53]

The structure of the undergraduate architecture curriculum illustrates this "diversity of attitudes and media": there is not a single required subject in the undergraduate program. Curriculum time is divided among four elements: subjects in science, humanities, and social science areas, the education base common to all departments in the university (50%); restricted electives (15%); planned electives (18%); and unrestricted electives (17%). This leads, in four years, to the degree Bachelor of Science in Art and Design. In some respects, however, the curriculum is not so open as the figures quoted might have it appear. For students who intend to continue their studies on to the professional degree, Master of Architecture, the planned electives are in architectural design. About 85% of the department's undergraduates study architectural design, normally during their third and fourth years.

The department has no required sequence of design subjects; rather, students are free to choose from among the studios available to them each term (normally four to six different subjects). Studio classes are grouped into three levels on the basis of increasing degrees of complexity of design work, and students usually take two studios at each level in the course of study which leads to the Master of Architecture degree.

Precise statements characterizing work at any of the three levels remain as areas for faculty debate. In the absence of department-wide coordination of studio work, there is little continuity across the various subjects in design.

From among the four first level studios taught during the fall term, this particular class was selected as being an excellent representative of what may be called a traditional approach to architectural design teaching. Professor Harris, the instructor in charge, is regarded by architectural educators and professionals alike as an eminent teacher and designer; he has had wide experience in architectural practice and has had influential roles in academic life. He was assisted on two afternoons a week by Ms. Lewis, a practicing architect with one of the better architectural firms in town.

Of the nineteen students who originally chose this design studio, seventeen completed the semester: one student dropped out early in the term and another failed to attend class, thus receiving an incomplete. The remaining seventeen, ten men and seven women, included:

11 junior architecture students
1 senior architecture student
3 cross-registered senior students, majoring respectively in art history, fine arts, and molecular biology and architecture
1 senior civil engineering student
1 first year graduate student in architecture

(Beyond this point in the discussion, the gender of all students has arbitrarily been changed to masculine to protect individual identities.)

Their reasons for studying architecture varied widely. About half the class became interested in architecture after considering a scientific or technical course - chemistry, engineering, computer science, construction - while others came from a more artistic background - visual studies, fine arts, or art. For all but three of the students, this was the first design subject in architecture, and a number were using it as a basis to "try out" the field. Two students had family connections to architecture or construction, and two others had had office experience in an architectural firm.

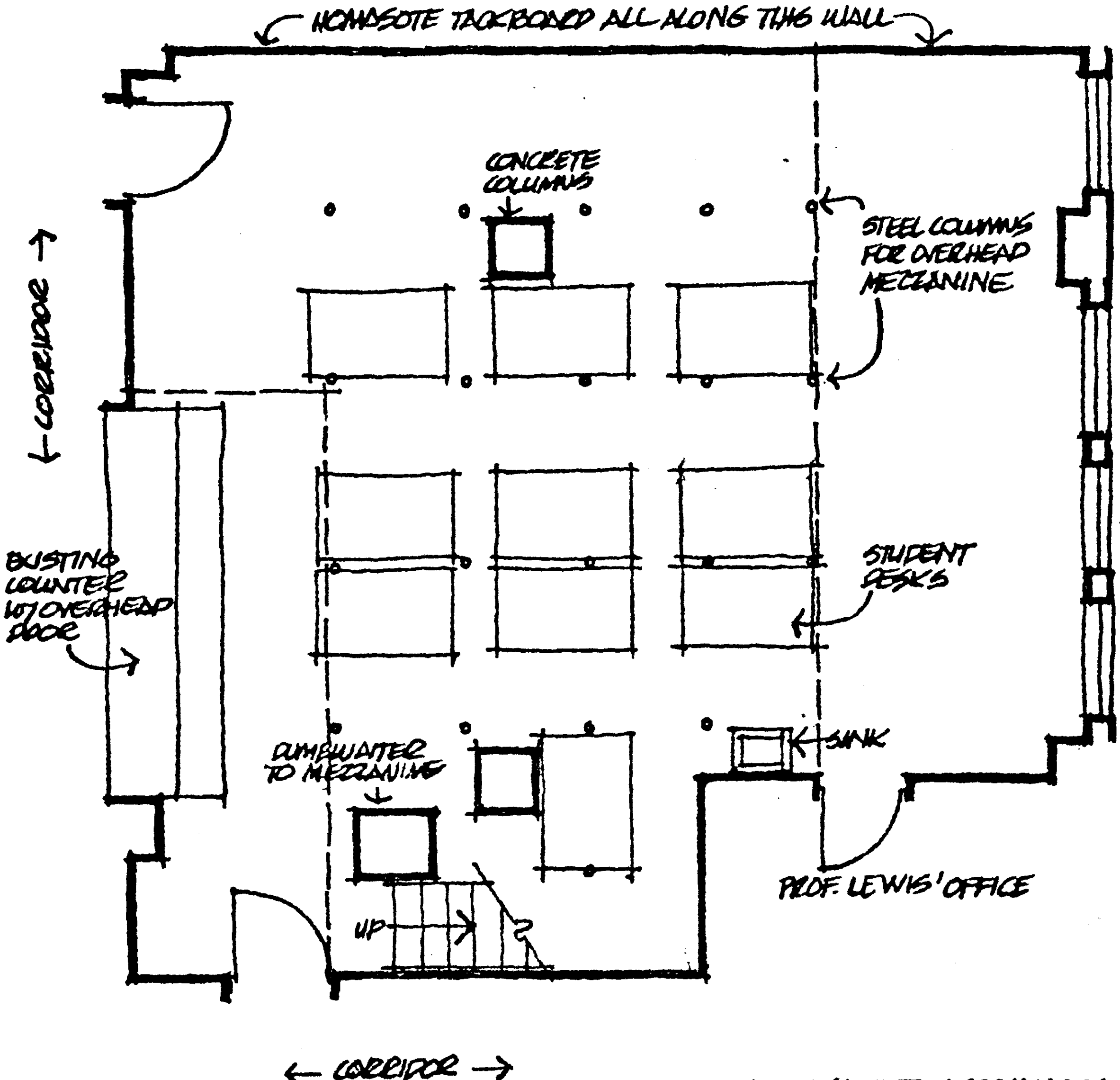
> I found engineering courses so technical that I decided on architecture.
>
> I had considered being a computer science major. I want to investigate one more design course, possibly as a humanities major.
>
> I came here for a science or engineering education and was in chemical engineering for two years....I found chemical engineering awfully boring and began last summer to think seriously about what I would be doing in that field.
>
> I liked visual design problems, structures, and building materials (classes)....I'm still not totally committed to architecture.
>
> I've been really interested in art from the third or fourth grade, but art is not an easy to make a living. Architecture seemed a way of keeping the art, by combining it with building.
>
> I decided to be an architect at age 11. I couldn't draw well enough to be an artist, so I decided to be an architect.
>
> I took three years of drafting in high school and loved it.

Just as the backgrounds of the students varied, so did their career goals. The class aspirations included urban design, computer systems design, art, industrial design, medicine, and civil engineering/architecture, in addition to more typical architectural careers of private practice or governmental work.

The studio met on Monday, Wednesday, and Friday afternoons from 2 until 5 p.m. in a space geographically remote from the majority of the architecture department's offices and teaching areas; until two years ago, the classroom had been the instrument shop for the electrical engineering department. The space, being high-ceilinged, came equipped with a steel frame mezzanine over three quarters of the floor area; there was also an abundance of electrical outlet boxes. Both upper and lower levels were utilized to provide sufficient working space for the class. In most cases, working surfaces for students consisted of unfinished 2 by 4's. Professor Harris assembled most of the desks and also installed wire cross braces on the existing stock of rickety wooden stools. "Homosote" board nailed across one side wall provided the major vertical display space; a moveable chalk board was also provided. (See sketch)

As initially outlined to the class, the semester's activity was to begin with a series of four short problems, each lasting from one and one half to two weeks and alternating focus on analysis and design, and conclude with a major project that would extend over the final five weeks of the term. In actuality, this schedule was maintained fairly closely. The class began with sketch problems (a number were provided from which students could select one), all concerned with designing an interior space for residential use within a given enclosing shell. This was followed by a project in neighborhood analysis: selected areas of surrounding communities were assigned to teams of students for investiga-

STUDIO OF PROFESSORS KIRK & JAMES



MEZZANINE ACCOMMODATED 9 ADDITIONAL DESKS

SKETCH PLAN OF ARCHITECTURAL DESIGN STUDIO tion, at both micro and macro scales, of the social, economic, physical, and visual characteristics of the place. Out of this investigation came a package of comparable statistical and qualitative data on five urban neighborhoods; in the next project, sites were identified in four of these settings onto which projections were made, in a feasibility study, of new housing for the area.

Up until this point in the term, in the seventh week of classes, Professor Harris's studio has been sharing projects and general review sessions with the adjacent first level studio of Professors Kirk and James. (Design instruction was given separately.) Now the two classes diverged; Professor Harris's studio broke the pace of projects and spent some time on developing facility at freehand drawing. Students were, from the first, asked to keep a sketchbook and to practice drawing in it throughout the term. Class time during the eighth week was organized so that the instructors could assist students in their drawing as they worked.

The fourth and final project of the term developed out of the third. Students expressed a desire to continue (with some program modifications) the work begun in the feasibility study; to the design of the site plan now was added the design of individual dwelling units. Before most of the class began on project #4, however, they had an individual session with both instructors during which past projects were reviewed and suggestions were made for consideration during the final project, which extended over the last five weeks of the term. (A summary of the semester's chronology, together with the problem statements distributed to the class, may be found in Appendix C.)

Totalling the instructional time according to its use, one obtains the following distribution of the instructor's time for the semester:

desk crits	35 hours	38%
group instruction	19 hours	20%
class work without professor's input	13 hours	14%
general reviews	13 hours	14%
individual student reviews	8 hours	9%
others not included in the above	5 hours	5%
	93 hours	

Clearly, the major portion of teaching time was spent in desk crits, where discussion and elaboration was focused on the individual student's work. Desk crits were a combination of visual and verbal communication between the professor and the student; gestures and sketches were as important as the verbal transactions which could be recorded on paper. Crits generally began when a student working at his desk was approached by the instructor and greeted to determine if the professor's intervention was desired: "Well, how is it coming?" "How is it working out?" "Any new insights?" The introductory inquiry usually found the student ready with questions or problems about his work, so the instructor would bring over a vacant stool, sit beside the student, and listen to his description of the work thus far. Very soon thereafter, the professor would begin to raise questions about ambiguous features or unclear reasoning; from then on, the student tended to say less. In general, the unwillingness to challenge the instructor could be attributed to a number of factors; in this instance, it seemed to me to be deference to the instructor's experience, a reflection of the respect in which he was held by the class. Sketches on tracing paper showing alternative concepts diagramatically or rendered pictorially would be drawn by the professor as he commented and gave suggestions about the design. Two crit sessions around the sketch problems early in the semester illustrate this general procedure.

> Professor Harris walks over to a student at work and asks, "May I help you?" The student explains what he is attempting to do in designing the apartment's interior; he plans a change of floor level for privacy.
>
> "There is only one man living here, so why would he need privacy?" asks the professor. "It was not intended in this problem that the floor level would be changed. Why do you put the kitchen in this corner?" The student corrects this statement; his drawing has been misread since the kitchen is not in that corner.
>
> "One of the problems in this problem," the professor continues, "is that this (given building) is not a very big space. Like this space *(gestures around the studio)*, it is divided up by things you can't change. These columns *(points to studio mezzanine supports)* are 7 1/2 feet on center; yours *(points to the plan of the given space)* here are 9 1/2 feet on center. I think you want here to overcome that, to find ways of making all of this one room, if possible. That is not easy to do." In response, the student explains that he is trying to separate the kitchen from the rest of the apartment.
>
> The professor, taking a roll of tracing paper and drawing as he talks, asks, "Is it possible to put the kitchen over here?" He figures out the dimensions required for sink, stove, refrigerator and counter space on the edge of the sheet. Then, outlining the location of columns heavily in plan, he draws a way to get into the space, locating the bath, bedroom, and circulation areas. Next he shifts the walls around to reduce the area devoted to circulation, devising other ways to incorporate elements of the plan into the limited available space. The student has sat

silently during this time, watching the pencil move across the paper and listening to the reasoning which accompanies the drawing. After a number of ideas have been drawn superposed on one another, the instructor comments, "Now you must find ways to unify this space. Are you going to do anything to get light in here *(points* to the apartment areas removed from the exterior wall)?"

"Yes, I was going to try putting one skylight in somewhere, but not near the windows." The professor's pencil comes out again to draw some alternative kitchen arrangements with necessary dimensions. Possible locations for the living, entertaining, and dining areas are also indicated.

The student now seems satisfied with the comment upon his work; the professor moves on to the desk of another student who is waiting for Professor Harris to be free. The second student has two different plans, including furniture layouts, which can be overlaid on a simple outline plan of the given space. These he briefly explains to the instructor.

"I believe your furniture is a bit out of quarter scale," begins the instructor; he then sketches out dimensions for typical residential chairs, sofas and tables. "The problem with the first plan - do you really need three toilets? Is there some way of arranging the entrance for a three-way choice - to the living room, the kitchen, or the bedroom/bath area? That would seem better since the space is so small. The problem with the second plan - it is too much a prisoner of the columns. There is no space in it bigger than eight or ten feet, and that is confining. The sofa right in the corner is not comfortable; generally a sitting area needs a ten to twelve foot diameter across it for comfortable conversation, and you can't do that here." Professor Harris has been drawing as he talks, sketching out typical living room furniture arranged for conversation, dimensioning all of it to show that ten to twelve feet are required. He continues: "The bedroom and bath are not accessible from the entrance: one of the first things one might wish to do when coming home is to wash up and change clothes. You may have a guest waiting for you and wish to wash up before meeting him. Having two entrances is perhaps a good idea, but there is probably no need for double doors here. It is a strong statement of monumentality and openness which is not needed here since the atrium is not for the owner's use."

At this point, the professor reaches for a clean piece of tracing paper, overlays it on the plan, and begins to draw. Starting with the kitchen, he suggests a reduction in area given to it, proposes a rectangular dining table with the short end placed against the wall as a dining area which can seat two to four persons in a minimum of space, and indicates that work space which at present is not explicitly identified on the plan needs to be considered.

"What about light?" The student responds that he had not thought about anything but artificial sources; the instructor recommends that he consider some natural light as well. A proposal is also made to provide natural ventilation for those times when the air conditioning is not needed.

The student has a number of geometric designs using the floor tile; several of these are admired by the instructor: "Isn't it amazing what you can do with one simple pattern?"

The crit concludes with some questions from the student about the size of presentation sheets and the requirements for drawings. The instructor suggests perhaps an isometric sketch would be a useful way to represent the space. He makes one freehand to demonstrate what might be shown this way. Seven or eight other students stand around silently to watch this drawing take shape.

The amount of group instruction, which occupied about a fifth of the class time during the entire semester, decreased markedly in the last six weeks of the term. Under group instruction are included general discussions around projects, lectures on drawing, site analysis, and construction, and other situations where one or more instructors presented information before the class as a whole. These sessions, lasting from thirty minutes to three hours, were conducted at the chalkboard and/or tackboard, with students standing or sitting around on stools, table tops, or the floor. The manner of presentation tended to be informal; teachers spoke without prepared notes, and there was seldom much participation from the class. Some students took notes on what was said; most sat with writing implements and paper at hand.

The category, "classwork without the instructor's input," includes primarily the period during the second project when teams of students were out at the various sites gathering information. On those days, few or no students showed up at classtime in the studio; after attending to problems any of those that came might have, the instructor would leave the empty room.

General reviews, or juries as they are commonly called, were the evaluation events which terminated each project. Students often worked extra hours prior to reviews in order to complete their design drawings and models. Persons not associated with the class - other faculty or outside guests - were invited to examine and comment upon the students' work along with the instructors in charge of the studio. Reviews were held either in the studio itself or in the studio next door, which had a larger tackboard area and more room for numbers of people to gather around the work. Guest critics were generally given a synopsis of the project statement, either a written copy of a verbal summary, and then the review began, each student individually explaining his design and then receiving comment upon it. Three reviews followed this pattern and two did not: at the review of the first project, Professor Harris commented upon all the designs with almost no input from the student designers (there were no guest jurors present); and at the preliminary review held during the fourth project, a similar procedure was observed with the consent of the class. The general review of the third project was the first one in which students had to present their own design work (Project 2 had involved analytical studies along rather proscribed lines), and an excerpt from it gives some of the flavor of the session. This excerpt also includes an incident which impressed many students, as several students spontaneously mentioned it later in interviews. The critics were three other architecture professors, one from the first level class next door, one from a second level studio, and one who was not primarily on the design faculty.

> Student A explained his scheme for the housing layout, a design which included houses on individual lots fronting on streets which former cul-de-sacs within the site. Professor #1 raised questions about the side and front yards thus created; he felt they were generally useless in layouts such as this one because they were too small to be good for much and they lacked privacy. Professor #2 had questions about the parking arrangements for the elderly; all dwelling units except the elderly were provided with parking next to the front door, while the elderly had to walk some distance from car to house.
>
> "You have only subdivided the land," observed Professor #3. "Your graphics show only blobs for houses; the sense of what to do with it and how to utilize it is left up to other people. Can you just brush all of this aside? What do you think?"
>
> The student had no ready answer.
>
> "You have a strong point in your favor, you know," continued Professor #3, "since people will tend to build as they wish despite what designers indicate."
>
> Professor #1 broke in. "I believe you have to do more than that. You should indicate the limitations and possibilities. You have a compacted suburban layout superposed on an urban neighborhood, without incorporating the merits of suburbia and without developing the advantages of the urban situation."
>
> Professor #3 gave a few examples where more detail in the design could be desired.
>
> "This is typical private land development," commented Professor #1.
>
> "So much good land is sacrificed here for automobile access to individual plots," observed Professor #3, referring to the roads and paved driveways indicated on the plan.
>
> "Maybe we should go on to another project," suggested Professor #1. "The point of disagreement here is that the person has solved the problem in favor of one criteria - convenience of parking to one's house - and hasn't solved others."
>
> "But the designer must address all the hot issues; he can't say he did not choose to solve some of them," said Professor #3.
>
> "I anticipate that people will fence their small pieces of land to obtain privacy," observed Professor #2. "This could have been shown better graphically."

Student B's project was next considered. His site plan involved a free-form rowhouse design with stepped building facades. The site had a great deal of open space, in contrast to the preceeding project; this generated jury discussion that perhaps Student B's buildings were not drawn at the same scale as was his site.

"There is no use for the exterior space indicated. Why?" asked Professor #3. The student gave a hesitant, equivocating reply. "You are dodging the issue," responded Professor #3.

"If you did not commit yourself in this design, you have missed a chance," observed Professor #1.

Professor #3 continued. "You ought to think of some of these things beforehand so they could be discussed here." At this point, Professor #2 tried to defend Student B's apparent lack of coming to grips with important aspects of the problem.

The student, having said nothing in his own behalf, breaks in: "The critics in this studio have not been useful to what the work has been. We want to think like architects, we want to think like adults, and we feel isolated." He went on to complain about the seeming irrationality of insisting on only one-story housing designs in the site plan, since at the required density there was not much one could do.

Professor #3 then declared that the preference for one-story design "was a bias, not a fact of life." He returned to criticism of the design. "What would be the piece of land I could acquire if I lived here?"

"I don't know."

"Why don't you know?" Professor #3 was angry by this point. "Have you never lived where people owned land? Did you not spend three weeks looking at urban neighborhoods? Criticism of the organization of the class won't get you off the hook. There are no lots shown here, no parking, houses half the proper size - where have you been? What have you been doing?"

There was a prolonged silence in the class, after which the reviewers moved on to the next project.

The remainder of the review was not this dramatic, but the excerpt above brings out several characteristics of review sessions. General reviews were supposed to last the length of one class period, three hours. With seventeen projects to be reviewed, this meant that the jury, working without intermission, could devote less than eleven minutes to each student if the time was equally apportioned. The combined time for the two reviews just cited was about one hour and fifteen minutes; they were the first two projects presented. As the end of the class time approached, the amount of attention given to each student project diminished sharply. On this particular day, several projects were not reviewed at all because the time ran out. (They were discussed at the next class meeting by Professor Harris alone.) The first projects examined always received the greatest share of the jury's attention. Students who want first or second could expect a rather extensive critique of their work, and students in the last half of the order got only superficial treatment. The determination of who would be first seemed to be an unpredictable process. Before the review session, students pinned their drawings to the wall on a space-available basis; the first ones usually located their drawings near to supplies of thumbtacks or push pins already in the homosote, with later arrivals filling in the gaps and attaching their work with tape if all the tacks were gone. The wall surface was sometimes zoned to group together similar projects (for instance, those dealing with the same site). Sometimes the jury began with the project at one end of the wall and moved across; sometimes they began in the middle and proceeded in a random fashion; it was difficult to anticipate when any given design might be reviewed.

Individual student reviews were held in the midpoint of the semester, when the first three projects were completed and a number of sketches had been done as well. The student reviews were held in a small office right off the studio, with the student and both instructors present.

Previous work was evaluated and suggestions for study in the fourth project (which had been announced) were given; a typical half hour session went as follows:

> The two faculty members are seated on opposite sides of a narrow rectangular table. The student enters and sits across from Professor Harris and next to Professor Lewis. The former removes the student's drawings from a pile of student work; he also gets out this student's written comments on the studio, answers to a series of questions asked in class during the previous week.

Harris: *(referring to the questionnaire)* You mention here that you would possibly want to include a small shop in the lower regions of the site. I believe this might be possible only if the whole area were developed that way. At present it does not look possible, does it? *(Silence.)* You also wanted to look further at the playground and other things. You want to keep on with this scheme?
Student: Unless you think it would be better to change.
Harris: I think it would be best to stick with the plan you have if there are things you can see to work on.
Lewis: What would you do with the elderly housing - keep it in or not?
Student: That depends on what it seems would happen. I mean, there are different attitudes in cross-discussion, what things are appropriate, you know... *(trails off)*
Harris: *(points to the plan)* You would have the playground over here?
Student: Yeah, and you didn't think this was a very good idea.
Harris: Well, it is not very central for the development but it would be an invitation to the rest of the neighborhood. *(points again)* You left out the buildings here which are pretty high and would cast shadows over part of your site.
Student: Should these be shown?
Harris: Oh yes, that's very important. What does happen there?

> No one is sure, so Professor Harris goes out to get a base map which will show the buildings in question. The student shows his sketches to Professor Lewis until Professor Harris returns.

Student: What are the issues? Because these are four stories, they can look down on anything over here?
Harris: Yes. One of the reasons for one story construction is private outdoor space; mixing levels of buildings will complicate things. The most mixed up thing in this plan right now is the street system.
Student: Yeah.

Harris: There is some virtue in the central provision for parking since then everyone can walk to his own house. *(He sketches out several alternatives - providing two parking areas, etc. - explaining as he does so.)* You need to get an adequate set of goals for the design.

Student: That was my problem - I could think up lots of things but I could not have it all come together. I should have had more stuff to show to you and Professor Lewis during this last project.

Harris: Having said this, what would you choose to do now?

Student: I'd start with the topography and try to figure out what it (the site) would really look like.

Harris: Another way to do that would be a model. It might be more of a help since then the contours would have more meaning. *(looks around for a contour map.)* One thing to keep in mind is that this *(indicates the contour map)* is not the natural terrain. You have to decide how to fit (your design) into it.

Student: The problem with the contours on paper is that you can't see what things mean.

Harris: You should look for material about 1/40" thick to make the model of.

Student: Buildings on different levels could be kind of nice, huh?

Harris: Yes, of course. The slope is not all that great.

Lewis: Then you can...

Harris: *(Continues his previous thought)* The ticket is to keep on at this scale and get an understanding of the site.

Student: What is the new program to be?

Harris: It's being typed now. *(He summarizes the contents of the sheet which will be distributed at the next class.)* What you should do is to make repeated plans like this, compare them, and try to combine the best features of each. That is very difficult to do - it's a synthetic exercise that will trade off various characterisitcs of many plans.

Student: Maybe I should draw the real shadows to see what it's like. (Shadows at present on the plan are shown as if the sun were shining out of the north, an academic convention for indicating them.)

Lewis: That would make them more realistic to you.

Harris: *(points)* This part of the plan is the most convincing to me. I see pedestrian circulation that is quite strong and private outdoor areas with quite a lot of variety. You have a tendency to have all the doorways at the same level.

Student: Are stoops desirable for the elderly?

Harris: No, they're not desirable for anyone. *(Pause.)* No, wait - think of attractive Italian hill towns. It's hard to make a sweeping statement like that.

Lewis: There's no icing problem there (ie., in Italian hill towns).

Harris: But there are several ways to get around that though.

(Begins to draw and talks as he does so about the entrance detail to some house.) That would be worth looking at - you ought to know these famous houses. *(Pause)* Well, good. You need to go to work. Produce some plans and compare them. *(He stands.)*

Student: I wanted some feedback. *(Hesitates.)* How am I doing? I mean, I'm doing something but I'm not sure. I don't see either of you as often as some others do since I don't always have something to show.

Harris: I think there has been an excess of lectures and general critiques. We propose more individual critiques coming in the second half of the semester.

Student: I had Professor Jones last semester for issues and things. I think of a lot of things. But it's hard to get these intentions down on paper.

Lewis: Yes, that's the hard part - getting things down.

The student asks for help with his perspective drawing; Professor Harris makes some explanations and sketches. The student asks when the sketch portfolios are due. Professor Harris gives him a final suggestion, to put borders around his drawings in the future. The student thanks both instructors and leaves.

In the individual student reviews and at other times when student work was evaluated, there was a difference between phrases used in praise and those used for negative comment. Problems cited in designs were almost always specific functional misfits: a playground located too far from most of the dwellings in the development, the difficulty of getting natural light and ventilation to spaces deep within house areas, many party walls, space-consuming parking configurations, curb cuts for driveways right at major intersections, irregular lot sizes and angles which would make house design more difficult, wasteful circulation inside and outside the dwelling unit. In contrast, praiseworthy features of designs were more indefinite: strong pedestrian circulation, clear expression of major ideas, consistency of organization, appropriate spaces to the context of the site, skillful handling of exterior spaces, competant design. Students were not always able to understand the criteria used in evaluation of their work; students whose work was praised were sometimes surprised that what they had done was considered good. "He praised the very features which he had tried to talk me out of in the last desk crit," was one student's comment on a general review session.

Thus far, description of the studio teaching has centered on teaching done by the two instructors. There was, however, another teaching network in the class, operated by the students themselves. The studio method of teaching traditionally has recognized that students can and do learn from one another; to facilitate this interchange, studios provide each student with a desk at which he can work, not only during class time, but at other hours as well. Since this was a beginning group of students, they had to be introduced to this mode of working. It was slow to catch on. With the exception of days immediately prior to general reviews, it was rare to find students working in the room before class or on days when studio did not meet. Inadequate facilities - poor light in parts of the room and the derth of secure storage for student equipment - as well as remoteness from the other studios contributed to the student's reluctance to use the room as it was intended.

> I would like to know, what is this wonderful thing about studio that I'm missing out on by not working there? The room has no safe place to leave stuff, no stools to sit on, and the light is not particularly good.
>
> We ought to do something to the studio room to make it look better, not so stark. Other studio spaces seem more messy, but somehow also more studio-ish.

Some students failed to perceive what benefits would be derived from doing their work in the studio; for the entire semester, almost a third of the class, despite repeated requests that they work in studio, produced their drawings somewhere else. The non-attenders offered the following reasons for not working in the studio: inconvenience (chiefly for the cross-registered students not living on campus), better space elsewhere (at home or in a dorm), and facilities problems (light and storage space which was judged inadequate). By the last weeks of the term, however, there was a growing cooperative spirit among the dozen students who came to class regularly and frequently worked there after hours; these people reported that the informal teaching from one another was personally and educationally valuable to them.

> I'm learning more from (a fellow student) than from either Professor Harris or Ms. Lewis. In the first place, (this student) is a good draftsman and that has helped me immensely. I don't think I could have done the course without him. I would have dropped out.
>
> The most learning occurs when the professor or his assistant come around and look at your work. No, wait, I have to say that's equal to what you learn from other students and their work - it's easy to underestimate the amount of that.
>
> It's amazing that it looks like there are so few people who don't do the work at all. Some don't work in studio, and some people work here only sporadically. I agree with Professor Harris's request that everyone should work in the studio. I would not be where I am if I didn't work here.

VI.

OBSERVATIONS ON THE CASES

In considering the work of the two design classes, a basic difference in the character of design problems undertaken was observed, a difference which contributed to the "engineering" or "architectural" quality of the cases studied. Mechanical engineering design appeared to operate in a range more closely bounded by technical constraints than did architectural design: the impact of physical laws, the properties of materials, and geometrical principles was evident throughout the design process on both projects undertaken.

> "The ratio of force to mass will affect acceleration - you want to minimize dead weight."
>
> "Traction is determined by materials; friction you can do something about through design. That's what design is all about: you have _n_ choices, and you try to select the right ones to do what you need." (illustrated with equivalents on board)
>
> "To minimize bearing friction, it is desirable to have a small axle. That's the reason watches have needle bearings." (illustrated with equations and a needle bearing sketch on board)

These technical constraints imposed substantial limitations on the designer's activity. Indeed, it was all most of the class could do to satisfy themselves and the instructor that fundamental operational requirements would be met by the design; no one spoke of appearance, form, or the like. The testing question during design consultations and reviews was Will it work? This was expressed in a variety of ways:

> What is the total force you are applying to the disc?
>
> This is the piston that pushes this mechanism?
>
> What keeps this whole thing from just turning this way? Say you have 450 lbs pushing into the paper. You have a bending moment here of 360 inch/pounds. Your stress is...(solves equation) Remember that? Now check to be sure this (crosssectional) area is sufficient to the amount of the load - if it's above 10,000 psi, you'd better worry."

There was no assurance from the outset of either project that a workable solution existed. Both faculty entries in the Potentially Great Race failed to perform within the time constraints set for the class (although, with much additional work, one racer did later achieve a run in record-breaking time). Despite the demonstrable need for a bicycle disc brake, no satisfactory device presently exists; several of the mechanical engineering faculty have considered the problem. Thus devices produced by the class, especially for the bicycle brake had the potential for becoming patentable designs. The uncertainty of workability could be tested, first by calculation, then by prototype construction, use and evaluation, and the department had available funds for interested designers to proceed with further development of their designs.

In contrast to the mechanical engineering class, the architecture studio's work was only remotely concerned with technical issues; in fact, their impact was so low as to be negligible. Rather than testing designs around the question of possibility (will it work?) the architectural projects were criticized around the question of choice (how will it work?). Since the technical feasibility of constructing housing on the sites considered was never an issue, the crucial questions in crits and general reviews centered around the reasons for the designer's choices:

> Which way do you think is the way lots should run on this slope?
>
> Why is this street so wide?
>
> Do you think you need curves in the road?
>
> Is there a reason for placing the living areas at the rear of the house?
>
> How do you explain the location of the playground here?

The designer's task in the studio was thus to find a system for combining certain known design elements - streets, lots, housing units, outdoor space - and then be prepared to defend his organizational principles. Several early crit sessions were usually sufficient for identification and eliminating the glaring functional misfits, like unworkable circulation schemes, stairs with inadequate headroom, or ineffieient interior plans, so the designer's efforts could be concentrated on refinement of his design into a consistent whole. "Workability" of architectural designs was tested in general reviews by questioning the student's conception and depth of thinking about issues raised by the jurors:

How do people use the common land?

Who will plant the trees and maintain the open space?

Who will shovel snow on the internal circulation paths?

These are not matters which can be resolved by a calculation or reference to standards: the student's understanding was tested against the critic's. Because the critic raised the question, one can assume he held an opinion on the subject; it was not uncommon to find crits on a jury holding opposing views on the same issue.

CRITIC #1 (referring to design just presented). This system of interior courts works. Contrasting this to other designs (just seen) where the public exterior spaces are unspecific and all about the same, this design seems to have a nice quality about its public spaces. They have a way of making many things go on.

CRITIC #2 But what happens to the city when you do something like this (i.e., build a development facing inward) with private interior courts? It's a response to a hostile environment perhaps.

Architectural design, being thus tested by conflicting attitudes, was in some senses moral education. The student was forced to take and defend the position expressed in his design work. Originality in the work lay more in the reasoning and attitudes expressed than in the things designed; the task was not to invent a new mode of urban housing.

Thus, distinctions in the content and process of design work was detected between the two classes. The elements which limited the options available to the architectural designers were, in comparison to the mechanical engineering situation, much wider in scope. Not only were the problems larger in scale, implying less attention to particular details of construction and assembly, but they also relied more on precedent and existing ways of doing things. In contrast, the mechanical engineers dealt with problems where the options available for exploration through design were more confined, narrowed chiefly by constraints of physics and geometry. The mechanical engineers were required to invent operational systems given the constraints while the architects were expected to innovate responsibly within a given context. Images and understandings of built forms were for the architects analogous to the physics of materials and mechanisms for transforming energy for the engineers.

In the process of design, a corresponding difference in the two cases existed, expressed as the value or priority placed on attributes of design activity by the instructor, acting as a surrogate client. The mechanical engineers, primarily concerned with the workability of the design, were never really interested in questions of appearance, elegance, simplicity, and the like. Just the reverse was true in the architecture studio. There crits were chiefly involved with questions of form, spatial effect, and visual quality rather than with determinations of the buildings' structural or mechanical functioning or their conformance with building codes and zoning restrictions. Had either class's designs been carried further in development, each would have had to address the areas of primary concern to the other before an implementable design would be finished. For the moment, it is of interest to note the inverse priorities in design of the two professions.

At an operational level, there was another difference between the two design classes: where the students did their work. Desks in the mechanical engineering design lab had to be used by other classes as well, and the room was locked during nights and weekends (except during the last week of the term). Students had to find space elsewhere to work and for many this became a pattern of not working in the classroom, even during lab sessions. They came to class with work in various stages of completion, stayed long enough to obtain a consultation with the teacher about it, and then left. When the class was given time during the lab period to work on a problem with the teacher out of the room, a majority of the students used the time for conversation about topics other than the work under consideration. By failing to use class time for design work, the students deprived themselves of the possibility of learning from each other. Students who in interviews mentioned learning about design from other students were in both cases referring to a friend in their dormitory or to one in another project.

Architectural design studios have traditionally provided each student with his own desk in the classroom, and the class observed was no exception. Students were exhorted to work there during class time and at other times as well. This ideal was slow in developing; it was not necessarily the procedure followed in other studios at the school; and certain attributes of the space (light, the shortage of secure storage) did not encourage students to work there, especially after class. But after the mid-term mark, about two-thirds of the studio could be found working in the room, at least during class time (the remaining third bringing in work for crits and then leaving). Radios and a coffee pot became part of the room's equipment. In interviews, students reported receiving significant assistance from their classmates; many characterized a "good" student as one who could and would interact with others around the work being done and who would in turn seek comments from others about his own work.

Despite these differences, three major similarities between the two design teaching situations were observed. They will be dealt with individually in the following pages.

DESIGN WAS TAUGHT AS PROBLEM SOLVING

Both cases observed were organized around problems to be solved through design. Lecture material in the mechanical engineering course was so selected and arranged that it would provide information that was pertinent to the design projects undertaken in the lab; group instruction and outside lectures for the architecture class were likewise supplemental to the problem-solving activity in design.

The problems to be solved, selected in advance by the instructors, permitted a progressive development of skills. The drawing and visualization skills, experience with shop machines, and work with material necessitated by the first project in "Introduction to Design" provided the basis for the second project which exploited disciplined conceptualization, graphic communication through standard engineering drawings, and an understanding of the behavior of certain kinds of materials and joints. The studio's projects likewise built upon one another, culminating in the fourth and major project: interior spatial design (begun in the sketch problem) was combined with contextural/exterior spatial design (from the analytic study of neighborhoods and preliminary site design problems) into the total design of a site and dwelling units for multifamily housing. Drawing as a means of communication was emphasized throughout.

Neither case explicitly taught a method of problem solving, although students in the mechanical engineering class were provided with more structure in their approach to problem solving through the weekly organization of the design laboratory periods. Before producing design sketches, students were encouraged or led to analyze the physical properties inherent in the problem.

> Professor: Who has done anything on the mechanics of braking? How about someone coming up to the board and showing what the braking mechanics are. *(A student does this.)*
>
> Professor: What are we trying to establish? Some specifications for what a disc brake is required to do. Can you flip over when the bike is stopped suddenly? *(Several*

students nod knowingly.) Obviously we want a disc brake that won't cause you to flip. We must find out what the limiting factors are.

Student: Can you account for the driver's skill?

Professor: Let me ask you, what will you do from a designer's point of view? Will a disc brake make it more or less likely that you will flip over? (More) Then we should spend some time talking about liability cases. The way the courts are going, it is best to assume the driver is an absolute idiot....I suggest considering the worst case and then designing the brake back from that.... Aside from flip-over, are there situations of maximum decelleration where the bicycle and rider might separate without flipping over the front wheel? *(A sketch on the board of a bicycle and rider are used to discuss the center of gravity and its possible shifts).*

Professor: How fast should you stop? What then is the decelleration? *(The class works on these.)*

Professor: All of you should consider, since you haven't before, what is the relationship of other parameters needed in order not to flip? Do you understand? *(He restates the question.)* Then extrapolating that for a given geometry, what is the impending doom? *(Class works on this.)*

Professor: Do you see that the limiting condition is when the back wheel produces no force? *(The class does not; the instructor explains the reasoning leading to this conclusion step by step.)*

Professor: I want you each to sketch down a disk brake together with all the parameters you think are important. *(He writes on the board)*:

1. Limiting torques on disc (no flip-over)
2. Methods for limiting maximum torque
3. Minimum torque requirements on disc for successful stopping (front brake only)
4. Forces on wheel and wheel supporting frame under worst conditions
5. Energy dissipated in disc brake under worst condition
6. Contact force requirements on braking-pads

All of these things I really wanted you to go through before today, but since no one has, I want you to go through the exercise now. Keep in factors such as

> friction as parameters. I want you to put down the mathematical basis for these things.

After this consideration, they were urged to propose a number of concepts, evaluate them, and then develop the most promising one. Problems in the architecture class were begun in a somewhat loser way: introduction of the problem statement was accompanied by faculty comments before the class about the major issues involved in the design: street noise, the multiple use of space, attitudes toward public and private space, and so forth.

> Speaking about the attitudes towards the neighborhood and public space possible in housing site design, the professor outlined two extremes. One was a dead-end road, with houses set back 80 feet from it, surrounded by manicured front lawns and large rear yards; the other was a new development where almost all the streets were bounded by above-eye-level walls, with the visible open space all paved and devoted to pedestrians. "The choice between these two is partly subjective and partly cultural. Do it the way you think it ought to be, and do not try to second-guess the American public."

Both classes made use of precedent as a stimulus for the student designers; this was especially important in the architecture studio, where an understanding of the range of previous solutions to housing problems provided guidance similar to that which the mechanical engineers drew from principles of physical science. The raising of major issues to be dealt with in the design included in large measure the referencing of previous examples as illustrations: house plans from architectural journals were xeroxed and posted on the wall; the faculty members in crits would refer to other buildings or environments which embodied ideas worthy of consideration in the student's own work, as in the review session on pages 96-98. In "Introduction to Design," the class examined and discussed disc brakes from automobiles and snowmobiles, but details of their design was not nearly so central to the student's design work as was the case in the studio.

Most students in both classes accepted the problem statements as written by the instructors. Difficulties arose in each class when one student, in the course of working on the given projects, desired to change some of the premises on which the problem was based, that is, to redefine the problem in light of his individual work.

In the "Introduction to Design" class, the deviating student designed a "bristle brake" which was more of a drum brake than a disc brake. From the way he described the development of his design, it appears that this departure from the disc brake concept occurred because of the way he thought about the problem, not because he intended to define another braking method; his concept was to stop the bicycle in a manner that lay somewhere between interfering with the spokes of the revolving wheel (as with the stiff cards children often fasten to the frame) and stopping the wheel suddenly (as by jamming a stick between the spokes and fork of the frame). The maverick student in the architectural studio took exception to the hypothetical mix of family sizes to be accommodated in the housing design. He identified the recently-immigrated Portugese families which lived nearly as the persons most in need of decent housing on the proposed site, and consequently undertook to understand their special housing problems and to design for their considerably larger (17 person) family groups instead of following the guidelines drawn up for the major term project. The instructors of both classes responded to the student-inspired redefinitions in a similar manner: each allowed the student to pursue his individual line of inquiry. Their intellectual generosity in doing this was not without cost. It placed the teacher in the awkward circumstance of having to give advice in areas not planned as being part of the term, areas in which perhaps he did not feel qualified to give adequate guidance. Another set of information, not included in the lectures or other course material, was needed to assist one student while the remainder of the class worked on as before. In neither case did the time and/or resources seem to be available to provide the extra help required. (As a personal reflection, I do not know how this might be resolved in the general case.)

For whatever reason, both students who chose to work rather independently of the class were left more on their own than either student or instructor might have intended originally. When the student ventured into new territory, he left behind the experienced guide. The architecture student in particular became irregular in class attendance (presumably because of fieldwork being done to understand the Portugese client group) and expressed dissatisfaction with the critical input received from both instructors. (This student had been critical from the first of the class; how much of his insistence on reworking the problem was done in order to rebel against the teachers' organization of the class, and how much the redefinition was a real attempt to follow up strongly held convictions about the client, is hard to say.) Neither student's project fared as well in the final review as did other projects in the class; both were criticized for fundamental faults which, in the work of other students, were identified and corrected much earlier in the design process. The engineering designer was told unquestionably by a reviewer that his specified brake material (plastic) would be unequal to the heat generated by braking friction, although the independently original thinking which lay behind the design was admired. The architectural designer, in a more severe jury session, was cited for inadequate comprehension of the client group which he studied as well as for major deficiencies in the resulting design, a plan providing four-story walk-ups containing split-level apartments. Larger families were housed on the upper floors.

> I can't possibly read how to get into that apartment nor can I understand the window situation at all, except on the two (apartments) which are shown in detail, and then I can't even tell about the entrance.
>
> Do you realize that it's probably been illegal everywhere since 1890 to have bedrooms without outside windows?
>
> First of all, I <u>think</u> you can't get a mortgage for a building where you walk up more than 2 and one-half floors to an apartment, so this is a little medieval in terms of a walk-up scheme. The second thing is that it's very difficult for mothers with large families to gather their children when they go off to market, particularly when they have to navigate so many floors to do that.
>
> What you've drawn there, unless I misunderstand what others have said here too, doesn't say anything about that dialogue with people about what they want. At least, I don't see anything about it in those things.

These incidents raise several issues about design teaching.

I. How far should an instructor go in accommodating diversions from planned and prepared projects? If a class is organized to provide the information and expertise necessary for the design of disc brakes in metal, how does the teacher provide adequate resources for a student designing a drum brake in plastic? If a studio is to focus on housing for a theoretical range of family sizes, how does the instructor adjust for a student wishing to explore the special needs of an actual client group? Where must the line be drawn between individual student interests, possibly quite creative ones, and the planned class activity which will utilize the instructor's expertise?

Another factor is involved here as well: to what extent is the students' learning from one another impaired if a number of students in the class pursue different projects? The importance traditionally attached to peer group learning by architectural educators is reflected most directly in the space devoted to studios, where the notion has been to maintain a community of designers at work during the class hours and outside of them as well. DeBono, writing about the method by which creative problem solving (which he terms "thinking ability") might be taught, remarks that teachers must create "special situations which develop thinking ability directly because they are learning situations. The situations do have to be carefully structured so that students can learn from each other, for if the situations are loose the students are working on projects so different that this important aspect of learning is lost."[54]

Not only are mavericks detached from the expertise of the faculty, but they risk losing touch with the common group of designers formed by the class as well.

One might speculate that, particularly for a beginning course, it would be advantageous for the teacher to formulate projects carefully and then to insist that the students follow the program as presented. As all problems studied in classrooms are to some degree abstractions of real situations, the instructor should explain in which ways the problem being studied is artificially proscribed to permit certain aspects of design to be studied adequately within the time and teaching resources available to the class. Given the high degree of dependency upon the design instructor which is involved in design teaching, it appears reasonable that class work should be based largely on his expertise. In both cases observed, the instructor was the major resource for design information, assistance, and criticism; his effectiveness in that role was markedly reduced when the work was diverted outside his field of knowledge. Imposing reasonable limits on the problem to be studied becomes a dilemma for student and teacher alike: it must be an acceptable compromise between the teacher's domain of competence and the student's range of concerns.

II. There is another issue raised by teaching design as problem solving. How do students become involved in the examination of problem definitions if the essential scope of the project to be considered is implicitly set at the beginning by the instructor? Because design is a problem-setting as well as a problem-solving activity, one of its components is that of defining what the problem to be solved is. Throughout the design process, of course, the issue of problem identification and solution occurs and reoccurs at a number of scales, but in the two classes observed, reexamination of the decision (made by the instructors) about what was the issue to be solved, was not encouraged. The mechanical engineers were not asked to consider what happens to conventional bicycle brakes when they get wet and then to design a solution which would meet the proposed safety standard of stopping a bicycle from 15 mph in 15 feet under wet or dry conditions; they were asked to design a disc brake for the front wheel of a bicycle to meet the safety standard. The architects were not asked to consider a certain neighborhood and propose appropriate reuses for a portion of that neighborhood; they were asked to design housing on specific sites at a given density and for a given range of family sizes. Without suggesting that the less specific statement of either of these projects should have been given to the classes (both involve issues which probably exceed the abilities and comprehension of beginning students), one might argue that introductory design classes might introduce students to the tasks of problem identification as well as problem solution; the two are complementary parts of design, very dependent on each other, and a more balanced view of design might result if both aspects were covered in one course. Students could discover that, in design, one must strike a balance between considering the ever-widening fields surrounding the narrowest definition of a problem and obtaining a problem definition sufficiently restricted that a design solution can be produced within reasonable limits of time and resources.

If one were to examine all the possible implications of either the bicycle braking or urban housing problem, one might literally spend years tracing down all the factors comprising the broadest statement of the problem, failing entirely to progress towards a design.

Outcomes from the informal design experiment made at the end of term seem to indicate that students did not after the exposure of one semester appreciate the necessity for examining a problem before proposing designs. In the experiment, each student was asked to design a chair; no more information was given unless the student requested more. Fewer than half of the students interviewed realized the vagueness and inadequacy of the "problem" thus stated by asking more specific questions: Who is it for? What kind of chair is this to be? The next task posed to students was to list, without drawing, the kind(s) of information they would want to have if they were to design a pair of shoes. All students were able to think of at least three different factors which could be considered, but only one realized that these kinds of information were the same questions one could ask about the design of a chair. Students produced a fairly comprehensive set of question areas one might use to narrow down the domain of design. A complete summary of responses to the informal design experiment may be found in Appendices E, F, and G.

DESIGN WAS TAUGHT THROUGH CRITICISM OF THE STUDENT'S WORK

In both classes, students were taught to design by first doing it, then receiving criticism or comment from the teacher about the work done. The basis for criticism was unity of organization, internal coherence and external fit, tested primarily through functional and logical analysis. Old texts on design identified four fields in which unity of organization might be sought: in logic, where it was called truth; in morals, where it was called goodness; in economics, where it was called usefulness; and in aesthetics, where it was called beauty.[55] While the words truth, goodness, and beauty were not employed in crits, design consultations, or reviews, the concept of unity underlying all of them was an important criteria for evaluation of designs. Design work had to give evidence of a consistent and coherent ordering of elements: brake designs employing complex linkages when a simpler mechanism would suffice were faulted as were designs which would fail to operate as intended; site plans where everyone but the elderly would be permitted to park near the front door were cited for poor logical thinking. Design work also had to demonstrate an adequate fit to elements with which the design would interface; brake designs had to be capable of being activated by the force of a normal hand grip; housing site plans had to respect existing neighborhood character and patterns of circulation.

Criticism in the two cases varied in the attention given to the fit of the design with human values and attitudes: this issue was much more central in the architecture situation, where people (though hypothetical) were the clients for the housing designs. In the mechanical engineering case, the "client" for the disc brake was the bicycle; the test of the design's fit was its interface with the frame and mechanics of existing bicycles. This observed variation in emphasis is perhaps indicative of differences found in professional design work in the two fields: the determination of success or failure of an architectural design is generally complex, depending on the values and role vis-a-vis the building of the one evaluating the work: a client, a user, an owner, an investor, a neighbor, a planner, a historian, a custodian, a builder. These critics seldom share values and hence they usually disagree, as did the architectural jurors. Traditionally, engineering designs, perhaps because of their smaller scale, appeared to face fewer moral or ethical issues. Operational effectiveness and mechanical compatibility formed the basis for criticism, and about these the critics seldom disagreed. It is a hallmark about contemporary engineering design that this view be expanded and consideration of the human client be made explicit.

The design professor in either class could, through crits or conferences with each student around his work, deal with each as a distinct individual; design teaching was, in fact, similar in many respects to the tutorial system of instruction. Gaudet's description of the studio <u>maître</u> in Paris at the turn of the century applies to the instructors observed;

> Here the design professor is a friend, a more experienced friend who guides his young friends, counsels them, studies with them, gropes with them, and hesitates with them. He does not have false modesty; he shows them how to search, how to find, and even how there are things which cannot be found. He is for his students, I repeat, an older friend; he knows, he has to know, their temperament, their nature, and their turn of spirit. He understands which one needs encouragement and which other requires stricter discipline; he knows who ought to be pushed and who ought to be held back. He will say, "That's quite good" about work which is intrinsically mediocre but in which he sees some progress; he will say, "That's very bad" about work which is really

> superior to the norm of the class but which, given the personality of its designer, shows insufficient advancement. Above all, he adjusts his comments to the nature of the student; he does not distort or substitute for the natural talents and potentialities presented by each individual. With good fortune, he will develop varied students who will be neither copies of one another nor of the professor himself.[56]

Design criticism or consultation sessions generally had three phases. In the opening stage, the student communicated, primarily verbally, the intentions and thought process which lay behind the drawings being examined. This explanation occurred both in private sessions with the instructor and in the public general reviews. As soon as the critic(s) had heard and seen enough to understand what was being demonstrated in the drawings, the remaining phases began. Logical contradictions or inconsistencies and operational difficulties were usually first discussed, with the instructor pointing out problem areas apparent to him. At preliminary stages in the design, there were usually a number of these:

> Where does the kinetic energy go?
>
> What keeps all this from just turning over?
>
> How great a mechanical advantage do you need? How much do you have here?
>
> Why do you want to enter off a busy street?
>
> When you have a pie-shaped lot and a house which must be half the size of the lot, it is very hard not to have a pie-shaped house.

One operational check which critics in both classes applied to test the soundness of designs was made by becoming a vicarious user. Professor Baker would mentally activate the brake to ascertain its operation:

> This is the part attached to the frame? And this is pushing here? This whole piece is floating?
>
> This is the piston that pushes this mechanism? And this connects to here?

Professor Harris would check out a given plan by investigating its adequacy under a number of hypothetical conditions:

> How would this work if the man came home with guests waiting in here to see him and he wanted to wash up before greeting them?
>
> How would one get from the entrance to the kitchen with several bags of groceries?

When the student's drawings were unclear, understanding the spatial and temporal sequences which could be implied from the drawings became more of a task.

A third phase of crits and design consultations was the proposal of alternatives from the design shown. Like the second phase, this stage was almost entirely in the hands of the critic; by questioning intentions or specific features of the student's work, the problem might be given a new perspective as the study was seen in a different regard. Alternatives suggested were always within the basic idea originated by the student, whether this was a hydraulic brake or a site plan with row houses. What had been four brake pads with a complicated mechanism for activating all of them might become two active and two passive contact points on the disc. What had been regarded as an awkward space between buildings could be seen as a sheltered courtyard for small children's play. Professor Harris was especially adept at the generation of alternative schemes for students' designs; he could sketch out several in the space of a few minutes, making note as he did so of the advantages and drawbacks of each:

Harris: These houses in here are along a street with a descending grade. I suppose the elevation will look something like that *(draws)*. Is that the way you want it to be?

Student: Yes, that's the way I visualized that. I don't know how else it could be done.

Harris: Let's see what are alternatives. You could have vertical breaks or you could slant the houses. *(He draws a sketch to illustrate these two schemes.)* I don't say that one is better than the other, but it's something to look at. In a building this long, you would need expansion joints. There are many ways to make that (building) more varied. *(He sketches a scheme utilizing the expansion joints to break up the long facade.)*

In addition to the substantive content of criticism given to design work, there was an emotional content embodied in the way the criticism was given. This was particularly evident in the architecture studio, where a number of critics with different styles reviewed student work. Both studio instructors, Professor Harris in particular, were calm, soft-spoken, and emotionally warm in their comments; in crits they were sympathetic to the student's problem, trying to understand his point of view in order to make suggestions which would advance the directions initiated by the student. Students reported positive feelings about this mode of instruction; because their ideas were taken seriously and sincerely, they believed the criticisms made of their work were legitimate.

> He was critical of your work but he gives suggestions for things you could consider to make it better, and he says good things about your work, too. He makes an attempt to talk with you about what you are doing. He's interested in students. He asks questions to get you to think and seems to enjoy himself in teaching.
>
> He was really encouraging. There are not alot of people around here who could say, "Yes, you have a good idea here. Go ahead with it." He would first bring out the good things in your design, then suggest things to make it better or that you might consider also.
>
> He would spend alot of time to work with students. He's very good in explaining himself, clearly and quickly; he could immediately spot my difficulties. He always had alot of helpful hints, small ones perhaps, but it would push me along.

In contrast, critics who were not so supportive in their remarks (like Professor #3 in the review excerpted on pages 93-94) were seen as vindictive, and the student confronted with this kind of behavior (Student B in that excerpt) discredited the professor and his remarks as being an unwarranted attack. Thus, critics considered "bad" by students were characterized that way in considerable measure for being unsympathetic to the student.

> He was very tempermental and would get upset with a student because he didn't like their work. He was too subjective and emotional.
>
> He would not listen to or comment on student ideas without being very critical, yet he offered nothing in return to guide you into something better. He also gave no reasons for a thing's being bad.
>
> He was viciously critical and made criticisms seem like personal attacks. "You made a mistake - how come? What's the matter with you?"
>
> He did not seem to have respect or understanding for your

> work. He was more like the outsider looking in than the insider looking with you.

An incident in the final term review, when two professors made substantively the same criticism about a project employing contrasting emotional sytles, confirms that at least for this student, the way in which comments were made was a substantial influence on their credibility. Only the remarks of the more sympathetic critic were taken seriously.

These observations about the content and manner of criticism raise questions about the development of the student's own capacity for self-criticism. It would seem that a primary goal of design teaching would be to increase the student's ability to design, that is, to enlarge his competence in handling design work. Through criticism, the teacher assists the students in their work by pointing out contradictions, raising questions about intentions, suggesting alternative approaches, and so forth. The student, acting on this comment, is able not only to raise the quality of the design but also to learn how to think critically about his work, an essential step in achieving independence from the teacher's or anyone else's critical input, relying instead on his own self-evaluative ability. The more facile a designer is at evaluating, reconsidering, and reformulating his work, the more likely he is to design well.

One might speculate that a situation which attempted directly to foster the student's self-critical facility would accelerate the rate at which it was acquired by students. From the cases observed, it would seem that such a situation should meet two goals: (1) it should make explicit through identification, demonstration, and practice useful strategies for the evaluation of design work; and (2) it should enable the student to cope with negative comment whether given sympathetically or not.

Through the analysis of comments made by design critics in the review and crit sessions, some potentially useful strategies for criticizing work are suggested:

(a) <u>The appropriateness of the solution to the problem</u>.

Does the design respond to the basic requirements set forth in the problem statement (square footage requirements, performance specifications, and the like)?

Has it addressed the major issues inherent in the problem?

Does it seem to be a plausible solution to the problem?

(b) <u>The internal coherence of the design</u>.

Is the arrangement of parts such that the design will function as intended?

Is there a logical and consistent rationale which seems to govern the placement of elements in the design?

Does the design function in the most simple and straightforward manner consistent with its necessary or intended properties?

(c) The fit of the design to its environment.

How does the design become part of the external world?

What effect has the external context had on the design and what effect might the design exercise on its environmental surround?

(d) The adequacy of communications about the design.

Are the designer's thoughts and intentions evident in the documentation of the design?

Can spatial and temporal sequences be readily inferred from the drawings presented?

Do all communications - verbal as well as visual - work together to convey the message intended by the designer?

Doubtless the list could be expanded, but it seems to cover some major design qualities. How instructors might encourage students to adopt self-evaluative routines might vary: critics could analyze for the student the way a just-completed design consultation was conducted, making plain the bases around which the work was examined; students could be assisted in desk crits or reviews to evaluate their own work around issues such as those listed; the class as a whole might discuss and propose remedies for problems encountered in self-examination of the designs drawn. Development of independent critical ability will not come easily: designers become attached to things designed and are understandably reluctant to discard them; criticism by its very nature questions the validity and rationale of existing designs. There would appear to be merit, however, in teaching students to become the toughest critic of themselves.

DESIGN TEACHING WAS BILINGUAL IN NATURE

Design teaching involved the simultaneous use of several communications tools, a new experience for most of the students. Education and previous experience had given most of them some proficiency in verbal language; for the design of physical things, however, visual language assumed importance. Sketches, a diagram, or a fully rendered image convey to the designer and to others the representation of an object with an immediacy impossible to obtain in verbal forms. And students were confronted with the necessity of developing skills in visual thinking and representation. Both classes acknowledged the importance of visual ability by devoting instructional time to the teaching of basic drawing skills and pictorial conventions. In the engineering class, this was done by starting with exercises in visualization, then progressing through a series of lecture-demonstrations, with the instructor either drawing on the chalkboard or showing slides to illustrate his discourse. Students took part in various drawing exercises in class, working in freehand, while the instructor walked around, noting and correcting before the class common difficulties he had observed. Pictorial conventions were presented beginning first with perspective and concluding with orthographic views. Students in the architecture class were required from the first to deal with standard architectural conventions of plan, section, and evaluation; a class period early in the term introduced the students to drafting instruments, the use of equipment, and a summary of drawing techniques. The architectural designers were also required to maintain a portfolio of sketches, and additional class time at mid-term was devoted to the development of freehand sketching ability and certain aspects of architectural rendering. Both groups of students had learned by the semester's end to equate design with drawing; nearly half of the students interviewed apologized for the quality of their drawings in the informal design experiment (see Appendix), being more concerned with the drawing's appearance than with the process by which the design was done.

For the mechanical engineers, however, use of another language was probably of greater significance to their design work; this language was mathematics. Mathematics was the form into which the design problem was translated at the onset of both projects; even though the students were presumably familiar from other courses with the concepts being used, it was the instructor who guided the class through the considerations of the mathematical aspects of each situation. (The excerpt of pages 108-109 is an example of this.) Students were heard to complain, "I've forgotton all the formulas," as they tried on their own to calculate the numerical basis for their designs. The importance of mathematics extended to design consultations and reviews; particularly in the disc brake project, the instructor in consultation sessions would ask what relevant values of forces were (What is the cross-sectional area here? And what is the force?) as he examined a design. In these sessions, he rarely sketched but frequently set up or solved an equation. The final review likewise concerned itself with some of the computational aspects of design.

The architectural studio placed a heavy emphasis on visual representation. Students learned early in the term the priority placed there on drawings; they received no real feedback on their work unless there was something down on paper.

> I felt here that people were very much into putting their thoughts on paper. There was a penalty on thinking since until stuff was on paper you could not get a crit.... If you did too much research or paperwork in this course, you would have nothing to show and would get no credit for it. I'm not sure this is a good thing.

Professor Harris felt that the drawings contained both necessary and sufficient evidence on which to evaluate the quality of design thinking done. To demonstrate this, he conducted two of the five general review sessions without having the students explain their concepts or defend their designs, using the visual material expressed in the drawings as the only information on which to base his comments. In one such review session, he began the examination of one project by "reading" the unit plans presented, drawing arrows at the entrances and locating where living rooms, dining rooms, bedrooms, baths, and kitchens were. A question was directed to the designer about windows on the plan which did not show up in the section drawing.

> "I find myself criticizing these plans on the basis of convenience; perhaps I shouldn't. I don't like having to go through the living room to get to the kitchen and bedroom - that seems to be

> a disadvantage. There ought to be a closet near the door for outdoor clothing; this can be used as a buffer or to identify the entrance. It should be possible for children to come in and out without disturbing adults in the living room.
>
> "The kitchen has a special need to be near an entrance for bringing food in and taking refuse out. It will have the most service traffic in the house and will also be the place where an adult staying at home will spend a great deal of time.
>
> "I would suggest putting a tint (on the drawings) over the plan of individual units in your row house scheme to illuminate the complex house arrangement. Perhaps this plan is too complex: there are rooms overhead which are not part of the lower unit, which can lead to undesirable noise transfer; a bath downstairs in one unit does not allow a downstairs bath in the other.
>
> "It certainly is ingenius though combining units this way to take advantage of the slope. You must think through your roof slopes - work out a roof plan and then modify the interior according to the difficulties which are bound to come up."

Professor Harris was an accomplished draftsman, and his desk crits are only partially reconstructed by recording the verbal transactions; his pencil moving over tracing paper was the center of attention for instructor and student alike. His freely-produced sketches could, with a few lines, delineate precisely the concept he wished to illustrate. There would be stretches of near-silence as the pencil moved over the drawing, pausing to consider an option, then marking out in decisive strokes an alternative for appraisal. Verbal comment was almost dispensable accompaniment to the images produced on paper.

Professor Harris's sketches made in desk crits were kept and admired by the student. Some of them would try later to decide which of the several alternatives displayed was the one Harris really favored; at the end of the term, two students described how this presentation of choices had affected them:

> My only complaint (about the studio) is that with two people (i.e., two design instructors) you get conflicting information. It's good in a way to see all the different ways of working out the design, but if you're pressed for time and just want a workable design, then it's a roundabout way to work. ...All my ideas and types of houses and designs have been conventional. Just now, through thinking, I'm open to other ways of doing it that probably wouldn't have occurred to me at an earlier time.
>
> I was not so satisfied with the course at the beginning because of a lack of understanding of Harris's teaching method. He told us one thing one time, then another contrary thing the next time. At first, I thought he was just not clear about what he was doing but then I saw that he was trying to have us see it from many points of view.

None of the students seems to have been aware that it was neither the drawings nor the alternatives which were the essence of the crit, but rather the process that produced the drawings and alternatives which they should emulate. The interaction between mind, hand, and eye established as Professor Harris considered a problem made every crit a demonstration of the way he worked in design.

Several points seem to emerge from these observations. First, the student enters the bilingual situation proficient in only one language, the verbal. The task of learning about design entailed practicing a new intellectual activity and testing it in an unfamiliar mode, either mathematical or visual language. For some students, that they learned to draw at all surprised them; but by the end of the term, all students in both classes had gained some degree of proficiency in graphic representation, at least to the extent it was taught and practiced in class.

Knowing how to draw or solve equations was one thing; knowing how to use specific verbal or mathematical skills in such a way as to advance one's design work was another. The instructor's superior grasp, according to the case, of mathematical concepts or visual images and how to apply them impressed the students but did little to explain how or why it was that the professor knew to apply this principle or exploit that visual idea. A real dialogue in either sketches or mathematics between professor and student was never observed, probably because of the disparity in their abilities to express ideas in the language of vision or mathematics.

But just as the teachers had a certain degree of success teaching drawing techniques to students with no previous graphic training, it is not conceivable that design instructors might succeed if they attempted to clarify how it was that they themselves knew to use certain elements of the new languages in design? To some degree, this will require that the students have some familiarity with a range of concepts that might be used. The mechanical engineers, for example, had solved equations, learned elements of static analysis, and been exposed to terms such as <u>force</u>, <u>torque</u>, and <u>friction</u> in previous physical science or other subjects; their problem in design was remember what these were and to recognize when these might profitably be applied to the work at hand.

The architects were at some comparative disadvantage, as there exists no compendium of visual images suitable for application in design. Students do come to the class with experiential knowledge about buildings, accumulated from having lived in them; teachers could encourage students to think back reflectively on their experience and to view it as a source of images and ideas for design. That students tend to do this at the present is evident from the informal design experiment. When confronted with a design problem, a majority of the students expressly relied on their past experiences with similar objects for qualities to capitalize on in their designs. (See Appendix E.) That students do not automatically think analytically about well-known previous experiences is attested by the number of times Professor Harris had to sketch out a conversation seating arrangement to demonstrate why a dead-end space 10 to 12 feet in diameter in a living room was necessary given the cultural spatial conventions and furniture of this society.

To emphasize that design is more than a craftily constructed drawing and to provide other things for students to consider as they worked, one might speculate about a situation where the instructor tried to be explicit about the origins of visual ideas he set forth as alternatives in crits. For a class in mechanical engineering design, one might hypothesize an instructor who would explain how he knew to take moments about this point or why he decided that the coefficient of friction was the critical factor in considering part of the brake sign. These changes in teaching technique would require that the instructor be a bit more conscious of the process going on almost automatically as he works on designs. Advanced students would probably not need such things to be mentioned; but for beginning students, it would appear that a more direct explanation of that which comes instinctively to experienced designers might accelerate comprehension of what design activity was about. This might also remove some of the cloud of mystery presently surrounding the way designers work.

AFTERWORD

As with any work which can only partially capture, recreate, and explain a complex phenomenon like design teaching and learning, this study raises more issues than it resolves. More work by persons equipped with different skills investigating a variety of situations will be required before a more extensive understanding of the design process, how it is taught and how it is learned, emerges. From this study, three themes suggest topics for further investigation; in concluding this report, I would like to explore each of them in turn.

I. Completeness of the present study demands better information about and understanding of the process students employ when learning design. Teaching and learning behavior in the studio or design laboratory appears to be of a different sort from that employed in the lecture format; further study into the student's adaptation to and functioning in the design teaching setting is necessary to complement the observations made of teaching behavior. Evidence from this study leads to three particular issues which might be explored.

First, there seems to be a discrepency between what students say they do when designing and what they in fact do, although this is not always the case. In the interviews, students were asked to describe the process they went through when designing something, and later in the interview they were asked to design something (a chair). The description did not always match the observed behavior:

ME6 (described) First I look at anything like it done before and cheat a little - it takes a genius to think of something entirely new. Then I have to think of the mechanics - the forces and moments - and figure out what it has to do. I have to think of all possible ways to do these things (mechanically) and I have to think in three dimensions, which is a pain if you're not used to it. Then comes the hardest step - I have to think how to build the mechanism, going back to the mechanics of the design.

(observed) A chair - how would I design a chair? Well, I've seen chairs collapse...(thinks awhile) That's all you said - design a chair? (Begins to draw) I don't know how my freehand sketching is this time of year. I'll start with a side view. (Draws.)

A7 (described) Finding out what the problem is - once I have identified the problem, it's a great first step forward. Then I try to get all the factors in the problem. Once I have the problem and the things which concern it, I can work on a solution.

(observed) A chair, a chair ... (begins to draw) I have to do all my sketching in plan, section and elevation since I can't do perspective. (Continues working.)

A11 (described) I start out with what's there - the neighborhood, people's use of it, other facilities, the view, the wind, etc. Then I take a part that looks particularly interesting and ask, If I wanted to design for this area, how would it be? Then I do the same thing with other pieces and it comes out pretty good.

(observed) (laugh) What is this? I just finished telling you I can't draw. (Begins to draw.)

A12 (described) I begin by looking at the program, what is given and the obvious possibilities inherent in it. Then I try sitting back and letting things come. Once I have a basic assumption or idea, the possibilities become more limited and work proceeds from there. The problem is having the time or energy not to depend on that first idea, that is, in having alternatives.

(observed) A chair...(Begins to draw, then explains:) The first requirement of this chair is that it has lots of space around it - it's a wing chair. Excuse me if the drawing is not quite level.

Argyris and Schon (1974) have found that variances between people's espoused procedures and their actual behavior are common in professional activities; they argue for the awareness and reduction of this difference as a step towards, among other things, improving receptivity for new ideas and learning. To the degree that design students also possess the characteristic of saying one thing and doing another, what in the teaching/learning setting might be altered to change this situation? Is the difference here between espoused and in-use behavior influencing learning about design, and if so, how?

The second area for investigation stems from observations made of the way in which students worked on design problems posed in the informal design experiment. Evidence from the visual design problem suggests that the first idea which occurs to a student remains a very powerful one: nearly three-quarters of the students interviewed (16 out of 22) came up with final designs that were minor variations of the first pattern which was laid out on the paper.

> Student ME7 arranged the rectangles down the center of the page, edges touching, with all but the square running parallel to the sides of the paper. The square was turned 45° to the remainder. (1) The pieces were shifted to a random arrangement at angles skew to the boundaries of the page, then (2) the design was rearranged in an almost-pictorial pattern (resembling a chair, I thought). This design was changed back into the initial configuration with the smallest rectangle now detached from the axial mass. The pieces were taped down.

> Student A13 laid out the rectangles at right angles to the edges of the page, spaced well away from each other. (1) There was a minor shift of 2 pieces, followed by (2) a major rearrangement, with the pieces at 45° to the paper's edges and then (3) a shuffle to a skewed configuration. From this, (4) the pieces were returned to an

> angular arrangement very similar to the initial arrangement; then (5) the 2 largest rectangles were moved down the page and (6) back to their initial positions again. (7) Minor adjustments in the location of smaller pieces were considered, (8) returning to the initial configuration. (9) The largest rectangle was shifted to the center top, (10) down, and then (11) back to the center top where it remained. The rectangles were taped down.

It was more difficult to document the strength of the first idea in actual classroom design work, due primarily to the intervention of the instructor as design work progressed. Observed changes during design development of class projects seem to indicate that not only in the informal experiment was the original idea the predominant one. In the interview, a number of students commented on the pervasive influence of the initial concept; several noted that they relied on it in designing:

> I get my ideas together and draw out some very important things at first glance. I work these into the site, then work down to details.

> I begin by looking at the program, what is given and the obvious possibilities inherent in it. Then I try sitting back and letting things come. Once I have a basic assumption or idea, the possibilities become more limited and work proceeds from there. The problem is having the time or energy not to depend on that first idea, that is, in having alternatives.

> I think alot and do messy drawings, not neat preliminary drawings as others (in the class) do. The general design just sort of pops into my head. I think I keep things in my head longer since I don't want to have an imperfect thing. I write down notes in essay form, then make drawings from them.

One might explore why these first concepts are such powerful ones and also probe the origin and development of these in designs. How does activity in the class (criticism or comment from the instructor, factual input to the problem, work of other students) affect an individual designer's concepts?

A third area needing investigation is that of the evaluation of student work. Evaluation is the means by which the student's learning is (in part) assessed; if an external judge is to determine something has been learned, there must be a demonstration of the learning in some manner which is reliable in measuring achievement. Evaluation by jury has its limitations: Jeremy Lowe, in a study of design evaluation in British architectural schools, has identified some 55 sources of variance in assessments made of design drawings by a panel; these include "conditions for viewing the drawings," the assessor's skill in selecting items relevant to formation of a correct assessment," and the "criteria specifically adopted as the basis for assessment."[57]

The Educational Testing Service in 1969 proposed methods for evaluating design work in architecture in a handbook prepared for the AIA. The document claimed "that more systematic instructional planning is necessary to respond effectively to increasing complexities and alternatives facing individual institutions, presently and in the future, and that measurement and evaluation can contribute significantly to more effective instructional planning."[58] By writing behavioral objectives, exploring measurement techniques (checklists, rating scales, essay tests, multiple-choice format questions), and indicating possible applications of these, the Handbook attempted to provide architectural educators with ideas for evaluation processes. It does not seem (thus far) to have had much impact on teaching situations; ETS probably underestimated the enthusiasm of educators for defining the elaborate objectives necessary and then systematically testing questions based on the objectives for their reliability, as recommended by the report. The primary beneficiary of the report's recommendations has been the National Council of Architectural Registration Boards, which has completely revised and computerized the national examinations licensing architects for professional practice. (The examination was developed under contract to ETS.)

An expanded and well-defined version of the evaluation forms used in the ASEE Creative Design Display might be a useful beginning for assessing work. Each of the eight categories on the more recent form - problem statement, conceptualization, background, creativity, final concept, final design, graphic presentation, and verbal presentation or model - is rated on a scale from one to five:

1 = unacceptable

2 = minimal (poor work)

3 = satisfactory (what one would expect with reasonable effort)

4 = above average (showing extra effort and interest)

5 = outstanding (approaching professional standards)[59]

With refinement to assure that the words used to define the categories and rating scales are commonly understood, such a device as this would minimize many of the important sources of variance in one section of Lowe's list. Clear statements of evaluation criteria might also help students criticize their own work; with an explicit basis for evaluation, one may be able to understand, at least in part, why design work was judged good or bad.

Distinction might be made here between two different types of evaluation schemes: one which measures in order to ascertain the adequacy of progress being made by the student, and one which measures so that rank orderings (first place, second place, ... last place) can be determined. The latter type is useful for competitive assessments, as in the Beaux-Arts design jury awards or the ASEE Creative Design Display; the former is more informative for the individual student in understanding his developmental strengths and weaknesses and is thus more suited for use in instructional systems similar to those observed in the case studies.

Formation of a standard of design proficiency, measuring achievement over time, would be a project that might yield interesting results for students and faculty alike. What is it (if anything) which distinguishes the designs in Appendix G that were produced by graduate designers from those of the beginning students? Is there an identifiable and definable progression in design work? Can it be assessed through examination of products alone or should the working process of the student be considered also in evaluation? How might this be accomplished? Design professions are not along in considering these questions; the implications raised by them extend across academic boundaries into almost every aspect of education. The issues are of sufficient difficulty and importance to warrant multidisciplinary attention.

II. Another perspective on design teaching might come through an examination of the educational process utilized by people who do not think of their work as design, but who nevertheless are involved in the selective deployment of resources to solve problems. Policy planners in both public and private life are an obvious group: so too are those who devise marketing strategies, plan the prosecution or defense in a court of law, direct the utilization of players and strategies in sports contests, plot military tactics, and others. All of these groups share certain attributes: they are dealing with constrained situations (e.g., the U.S. economic system, legal precedent and rules of evidence, player's talent, weapons, financial resources) where the problem to be solved (e.g., how to sell a product, obtain a conviction or an acquittal, win a game, defeat an enemy) has no one solution. In other words, they are dealing with design, and it might be worth looking at the ways they acquire skill at what they do.

All of these examples are concerned with the design of non-physical systems or things, in contrast to the designers of artifacts examined in the case studies. Artifact design is constrained both by the elements of nature and man, whereas non-artifact design is almost exclusively limited by societal constraints; the natural world has far less impact on the design of systems or strategies. It is interesting to note that the explicit societal restraints governing the design of tangible things (e.g., building codes, zoning regulations, industrial safety standards) come about through a process which is itself design, the design of non-physical things.

Looking at people who practice this type of design might be particularly interesting because most of them do not teach "design" in the academic setting common to the cases studied in this project. Not only might they provide insights on the process of learning design skills, but they might also provide a range of alternate teaching formats which engineering and/or architecture could explore. Are there more effective settings for design learning than the classroom? Are certain aspects of design better understood when encountered in non-academic environments? Business, law, or baseball may have some lessons to teach about synthetic problem-solving skills.

III. It might also be interesting to investigate the teaching procedures of some other fields where the mechanism for transmitting the art is, as in design, poorly understood. Music instruction, for example, may provide a parallel: how does one teach composition, conducting, or piano? There is generally a difference between instructional methods used for beginning and more proficient students. Instruction may also be considered in two sections, that dealing with skills and technique (the elements of counterpoint and harmony, how to beat time, fingerings for scales and arpeggios), and that concerned with interpretation and holistic considerations of performance (the development of musical concepts or thematic material, the appropriate character and style for Mozart symphonies, the "musical" execution of a phrase). For the former group, there are specific instructional methods for teaching these; methods for teaching concepts in the latter group are not so clearly recognized. Are there analogous patterns identifiable in design teaching? Can distinctions be drawn between elementary and advanced instructional methods in design, identifying problems and teaching methods more suitable to given ability levels? Are there classes of exercises which are or could be used to teach design skills? Does training in musicianship relate to problems involved in teaching certain aspects of design?

Design is not the only field which has trouble articulating its subject matter. It is interesting to note Maimonides's observation on theological instruction in the twelfth century:

> You must know that if a person, who has attained a certain degree of perfection, wishes to impart to others, either orally or in writing, any portion of the knowledge which he has acquired of these subjects, he is utterly unable to be as systematic and explicit as he could be in a science of which the method is well known. The same difficulties which he encountered when investigating the subject for himself will attend him when endeavoring to instruct others; viz., at one time the explanation will appear lucid, at another time, obscure; this property of the subject appears to remain the same both to the advanced scholar and to the beginner. For this reason, great theological scholars gave instruction in all such matters only by means of metaphors and allegories.[60]

The search for a pedagogy of design need not extend only outwards. Design teachers might be able, through experimentation with their own classes, to explore alternative teaching formats. Architectural studios might include a seminar or lecture period in the studio. The feasibility of producing a body of codified information about design, particularly in architecture, might be investigated. One wonders if there is a way the design instructor might transmit his understanding with less repetition about design than is possible through individual consultations; particularly for beginners, many of the points made in one consultation were raised again in the next. Professor Harris drew a sketch to indicate how living rooms require a dead end space ten to twelve feet on a side for normal conversational grouping at a number of desk crits; Professor Baker had many students check their designs with a free body diagram or a summing of mements about a certain point. Architecture might explore the approach used in mechanical engineering, where compilations of design information around specific elements (engines, transmissions) have been made; comparable documentation might be made of building types (residential, offices) for consultation by students. It may well be that generalized information about design would lack sufficient specificity to be useful and that "texts" on design would take the form of case studies documenting the work on a particular problem, including the information used and the procedure followed from beginning to end. Considerable experimentation would be required, first to see if a compilation of design information is possible, and second, to determine in what form the information is most convenient for classroom use.

This work began by assuming that a comparative study of design teaching would be worth doing. At the conclusion of the undertaking, I believe that it was indeed a useful approach to take, and, as there seems to be sufficient evidence of a common intellectual activity underlying architecture and mechanical engineering, it might even be interesting to extend the comparative approach into other disciplines as well. Looking at design teaching not as a student receiving criticism reduced, for me, the level of mystique previously characterizing the process. It also reaffirmed the conviction that design can be taught, raising the possibility that teachers might be taught to teach design and that students might eventually be taught how better to learn about design for themselves.

PERSONAL STATEMENT ON ARCHITECTURAL DESIGN TEACHING

1. I began this study with a conviction that design was a teachable subject, not solely dependent on natural "talent" or "gift." The experience of carrying out this work has strengthened this conviction.

2. The primary mission of university architectural schools, it seems to me, is to enable persons of ability with the desire to become architects to gain the competence necessary for being practitioners in the field. In working with curriculum committees at two different universities, I have become aware that some faculty tend to propose curricula and teaching practices which are better suited to students of exceptional aptitude or ambition. I believe schools should realize that most of their clients by definition do not have unusual abilities and those that do can and will assume greater responsibility for their own educations.

3. At virtually all educational institutions, the period of formal study is not sufficient to transmit the total scope of the art. This seems particularly true with design, where the development of design ability appears to require a longer period of maturation than is afforded by the years spent in architectural school. An important quality of education, it seems to me, should be to foster in the student the ability to continue learning years after graduation.

4. Despite the fact that there are many aspects of design activity

which do not yield to rational, universal formulations, there are some aspects on which teaching could focus. One such area is the process by which work in design is done; a student should be encouraged to reflect on this process - where his ideas come from, how he operates with information and the lack of it, what values are implicit in his work, how he deals with different concepts and attitudes, and how he resolves and refines the design. I believe that students who understand better how they themselves work at design should be better equipped to structure their own work patterns or to change them as the occasion merits. By their teaching style, teachers could make explicit their own reflections on these issues in design and encourage such reflection by the student.

FOOTNOTES

[1]Personal communication from Jerome S. Bruner to the author, May, 1974.

[2]Herbert A Simon _The Sciences of the Artificial_ (Cambridge: The MIT Press, 1969), p. 55.

[3]_Ibid_., pp. 56-57.

[4]Franke Huntington Bosworth and Roy Childs Jones _A Study of Architectural Schools_ (New York: Charles Scribner's Sons, 1932), p. 37.

[5]Turpin C. Bannister, ed. _The Architect at Mid-Century: Evolution and Achievement_ (New York: Reinhold Publishing Corporation, 1954), p. 192.

[6]Elizabeth Layton _The Practical Training of Architects_ (London: Royal Institute of British Architects, 1962), pp. 67-68.

[7]Dugald C. Jackson _Present Status and Trends of Engineering Education in the United States_ (New York: Engineers' Council for Professional Development, 1939), p. 8.

[8]L.E. Grinter, chmn. "Report of the Committee on Evaluation of Engineering Education" _The Journal of Engineering Education_ 46:1 (September 1955), p. 38.

[9]J. Herbert Hollomon _et al_. _Future Directions for Engineering Education: System Response to a Changing World_ (Washington: American Society for Engineering Education, 1975), p. 70.

[10]"Progressive Architecture Fifth Annual Design Awards" _Progressive Architecture_ 39:1 (January 1958), p. 81.

[11]"Progressive Architecture Tenth Annual Design Awards" _Progressive Architecture_ 44:1 (January 1963), p. 85.

[12]"Progressive Architecture Annual Design Awards Program" _Progressive Architecture_ 49:1 (January 1968). p.92.

[13]"The Twentieth Annual P/A Design Awards" _Progressive Architecture_ 54:1 (January 1973), p. 81.

[14]David A. Morton "Behind the Scenes" _Progressive Architecture_ 54:6 (June 1973), p. 85.

[15]"The Twentieth Annual P/A Design Awards" Progressive Architecture 54:1 (January 1973), p. 98.

[16]Personal communication from Ralph Blanchard Jr., enclosing copies of the evaluation sheets for the ASEE's Creative Design Projects, sent to the author, March 3, 1975.

[17]Ibid.

[18]Maitland Graves Design Judgment Test (New York: The Psychological Corporation, 1948), np.

[19]Bannister, p. 84.

[20]Quentin Bell The Schools of Design (London: Routledge and Kegan Paul, 1963), pp. 16-17.

[21]William Elgin Wickenden A Comparative Study of Engineering Education in the United States and in Europe (The Society for the Promotion of Engineering Education, Bulletin 16 of the Investigation of Engineering Education, June 1929), pp. 9-10.

[22]Bannister, p. 86.

[23]Bannister, p. 87.

[24]Hans Staub A History of Civil Engineering (Cambridge: The MIT Press, 1964), p. 181.

[25]Frank Jenkins Architect and Patron (London: Oxford University Press, 1961), p. 160.

[26]Wickenden, pp. 58-59.

[27]Frederic Goodson Higbee "A Short History of Descriptive Geometry" The Journal of Engineering Education 19:5 (January 1929), p. 505.

[28]James Philip Noffsinger The Influence of the Ecole des Beaux-Arts on the Architects of the United States (Washington: The Catholic University of America Press, 1955), pp. 106-110.

[29]John Burchard and Albert Bush-Brown The Architecture of America: A Social and Cultural History (Boston: Little, Brown and Company Atlantic Monthly Press, 1966), pp. 75-76.

[30]Bannister, pp. 187-188.

[31]Dexter S. Kimball and John H. Barr Elements of Machine Design (New York: John Wiley and Sons, Inc., 1923), pp. 1-2.

[32]Charles Riborg Mann A Study of Engineering Education (New York: Carnegie Foundation for the Advancement of Teaching, 1918), pp. 109-110.

[33]Wickenden, p. 96.

[34]Association of Collegiate Schools of Architecture Minutes (Mimeographed, 1913), p. 22.

[35]Julien Guadet Elements et Theorie de l'Architecture (Paris: Librairie de la Construction Moderne, 1902), p. 78.

[36]Royal Institute of British Architects Proceedings of the International Congress on Architectural Education (London: Royal Institute of British Architects, 1925), p. 27.

[37]Bosworth and Jones, pp. 184-185.

[38]Association of Collegiate Schools of Architecture Minutes (Mimeographed, 1931), p. 31.

[39]Ibid., p. 10.

[40]MIT Radiation Laboratory Radiation Laboratory Series Nos. 1-28 (New York: McGraw-Hill Book Company, 1947-1951).

[41]Cristopher Alexander Notes on the Synthesis of Form (Cambridge: Harvard University Press, 1966), pp. 10-11.

[42]Massachusetts Institute of Technology "Twelfth Annual Catalogue of the Officers and Students, with a Statement of the Courses of Instruction" (Boston: Press of A.A. Kingman, 1876), p. 45.

[43]Massachusetts Institute of Technology "Catalogue of the Officers and Students with a Statement of the Requirements for Admission and a Description of the Courses of Instruction" (Cambridge: MIT, 1906), p. 176.

[44]Massachusetts Institute of Technology "Catalogue 1906", p. 182.

[45]Ibid., p. 182.

[46]Massachusetts Institute of Technology "Catalogue Academic Year 1931-32" (Cambridge: The Technology Press, 1931), pp. 162-163.

[47]William R. Ware "An Outline of a Course of Architectural Instruction" (Boston: Press of John Wilson and Sons, 1866), p. 6.

[48]Massachusetts Institute of Technology "Seventh Annual Catalogue of the Officers and Students, and the Programme of the Course of Instruction" (Boston: Press of A.A. Kingman, 1872), p. 42.

[49]Massachusetts Institute of Technology "Catalogue 1876", p. 51.

[50]Massachusetts Institute of Technology "Catalogue of the Officers and Students with a Description of the Requirements for Admission and a Description of the Courses of Instruction" (Cambridge: MIT, 1911), p. 252.

[51]Leopold Arnaud "How Architecture Is Being Taught" Journal of the American Institute of Architects 9:4 (April 1948), p. 149.

[52]Massachusetts Institute of Technology "The MIT General Catalog Issue" (Cambridge: MIT, 1974), p.223.

[53]Ibid., p. 157.

[54]Edward DeBono Children Solve Problems (London: Allen Lane The Penguin Press, 1972), p. 11.

[55]Henry V. Hubbard and Theodora Kimball An Introduction to the Study of Landscape Design (Boston: Hubbard Educational Trust, 1967), pp. 16-17.

[56]Guadet, pp. 78-79.

[57]Jeremy B. Lowe "The Assessment of Students' Architectural Design Drawings" Architecture Research and Teaching 1:1 (May 1970), p. 34.

[58]Educational Testing Service A Handbook for Measurement and Evaluation in Design Education (Washington: American Institute of Architects, 1969), p.11.

[59]Blanchard to Moffett.

[60]Maimonides "Guide for the Perplexed" in Three Thousand Years of Educational Wisdom: Selections from Great Documents ed. by Robert Ulich (Cambridge: Harvard University Press, 1954), p. 653.

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APPENDICES

APPENDIX A Introductory Statement to Class

During the coming semester, this class will be studied by Marian Moffett, a doctoral student in the Department of Architecture and the Division for Study and Research in Education. She is doing a comparative study of beginning design teaching in architecture and mechanical engineering, using this class and a mechanical engineering project lab as case studies in her research. She will attend class meetings and would be glad to talk with any of you about her work, the course, design, architecture, or whatever. All information she collects will of course be confidential and will not in any way affect grades given in this subject.

APPENDIX B Schedule and Problems from "Introduction to Design"

SCHEDULE INTRODUCTION TO DESIGN

	Lecture subject	Distributed material	Laboratory activity
1	Organization and introduction Introduction of Project #1	Half semester schedule Project statement	Mini-project: design of a cantilever structure.
2	Design evaluation; visual thinking Sketching techniques; exercises	Blank paper Blank paper	Discussion of Project #1; generation of five alternatives.
3	One point perspective; exercises Two point perspective; exercises	Blank paper Blank paper	Discussion of design concepts; shop tour; selection of design idea.
4	Isometric drawing; exercises Oblique, axonometric, and orthographic projections; exercises	Blank paper, exercises Blank paper	Discussion of design details; vehicle construction in shop.
5	Graphic conventions; exercises Auxilliary views; exercises	Blank paper, exercises Exercises, "Control of Manufacturing Accuracy"	Shop work to construct vehicles.
6	Dimensioning and tolerances Engineering drawings; exercises	 Blank paper	Shop work to construct vehicles; testing of vehicles.
7	Preliminary trials Finals, A Potentially Great Race		Brief introduction of Project #2.
8	(vacation) Bicycle brakes	 Project statement, half semester schedule	(vacation)
9	Methods of assembly Automobile disc brakes (guests)	"Methods of Assembly"	Analysis of braking on bicycles; design concepts development.

SCHEDULE INTRODUCTION TO DESIGN (continued)

	Lecture subject	Distributed material	Laboratory activity
10	Forces of materials Kinematics	"Formulas for stress and strain"	Analysis of braking factors; discussion of conceptual designs.
11	Kinematics Kinematics		Consultation around individual designs.
12	Cams, springs, and snap rings (vacation)	"Design of Cam Systems" "Bolted Joints"	Preliminary design drawings to scale.
13	Conforce springs; bearings	"Design Guide for Conforce Springs", "Roller and Silent Chain Drives"	Completion of assembly and parts drawings for brake design.
	Mechanical power transmission	Summary tables on belt drives, gears, couplings, and mechanical clutches	
14	Presentation of five student designs (no class)		(no lab)

INTORDUCTION TO DESIGN

PROJECT NO. 1 "A POTENTIALLY GREAT RACE"

Object

To design and build a device which travels down a given track (see attached diagram), turns off a light bulb by interrupting a light beam, reverses direction, and travels back across the "start" line as quickly as possible.

Constraints

Material - Except for glues and adhesives (used only for bonding) and non functional decorations, the devices must be constructed entirely from materials supplied in the "kit."

Energy source - The energy used by the device to accomplish the objective must come solely from a change in the altitude of the center of gravity of the device.

Size - The dimensions of the device must always allow that it be entirely contained by a 2 foot cube which has its base in the same plane as the base of the device.

Time - The devices will be considered to be completed at 12:00 noon, October 22, 1974.

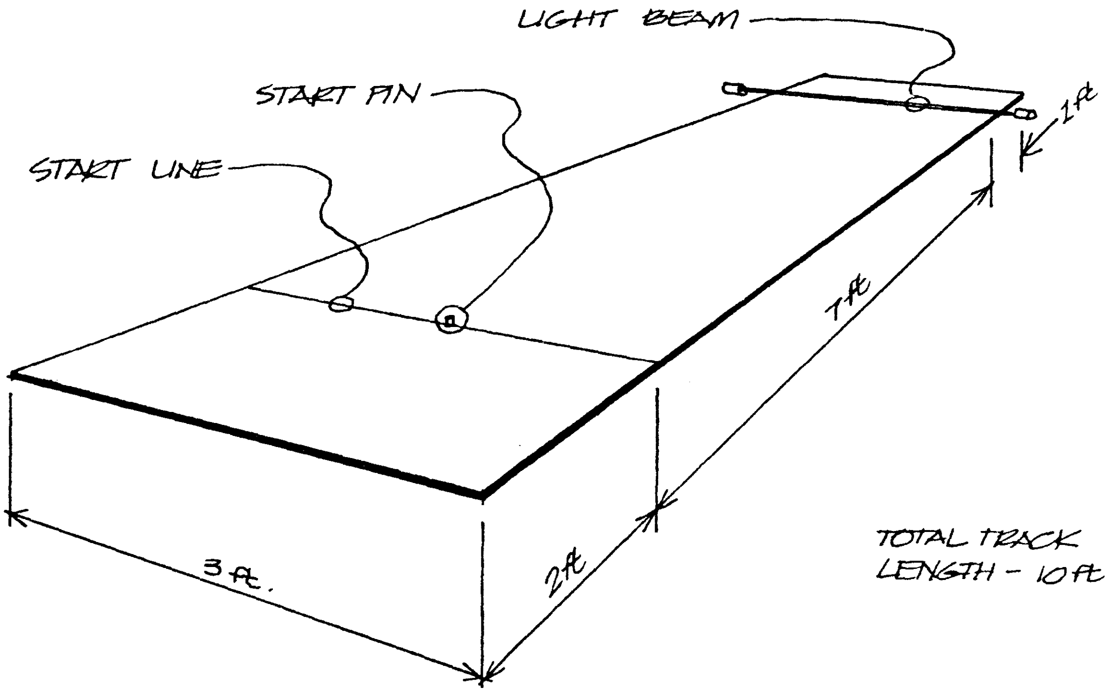
Evaluation

A "winner" will be chosen in a single elimination tournament. Races between pairs of PR's (Potential Racers) will be run on parallel tracks. The winner of each race will be the PR that first returns completely across the start line after having turned out the light. (Grudge matches will be run as time allows.)

Details

1. During competition, after the racer is called to start, a maximum set-up time of one minute will be allowed.
2. Kit materials may not be changed chemically.
3. Each PR must properly interface with the starting pin on the track.
4. A drawing of lots will determine first round competitors.
5. After the runoffs, the surviving PRs will be impounded and not released until 15 minutes before the finals begin.
6. After each PR's initial race in the runoffs, no major design changes will be allowed.
7. No manipulation of or interaction with a PR will be allowed while it is racing.
8. The tracks will be placed on tables -- competitors will be responsible for saving their PR's should they stray off the track.
9. The devices may contact only the top surface of the track.

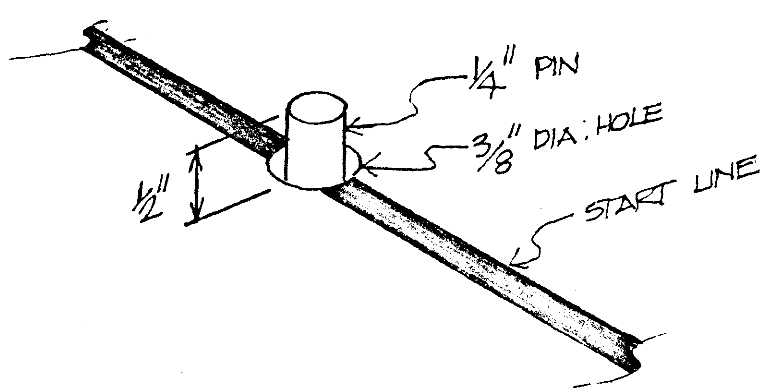
A POTENTIALLY GREAT RACE TRACK



TRACK SURFACE - PAINTED PLYWOOD

LIGHT BEAM - 3/4 INCH ABOVE TRACK, 7 ft FROM START LINE

START PIN - RETRACTS BELOW TRACK SURFACE FOR START



START PIN DETAIL

INTRODUCTION TO DESIGN

KIT OF MATERIALS FOR "A POTENTIALLY GREAT RACE"

1. 1 ft. x 1 ft. masonite sheet
2. 11" x 14" x .010" celluloid sheet
3. 2 white cardboard tubes, 1 with OD slightly larger than the other
4. 2 white plastic containers
5. 1 ft. strip of metal banding material
6. 1 ft. wooden strip
7. 1 ft. x 1/4" wooden dowell
8. 1 interdepartmental envelope containing a length of lycra thread
9. 1 ft. welding rod
10. 1 piece of string approximately 10 feet long
11. 1 pencil
12. 1 paper sack containing approximately 1 pound of sand
13. 3" x 3" x 1/4" piece of plexiglas
14. 2 pieces of polyflow tubing
15. 3 caster wheels
16. 4 rubberbands
17. 1 3" steel rod
18. 4 paper clips
19. 4 5" x 7" note cards
20. 4 8 1/2" x 11" sheets of paper

INTRODUCTION TO DESIGN

PROJECT NO. 2 DESIGN OF A DISK BRAKE FOR THE FRONT WHEEL OF A BICYCLE

Need

Conventional rim-type bicycle brakes suffer reduced performance in wet weather and when worn and/or not properly adjusted. Substantial background on the need for improved bicycle brakes will be given by Professor Meyer in lecture on October 31.

Schedule

Lab Sessions (in week 10)
Copies of complete layout sketches of the brake to be handed in to lab instructors.

Lab Sessions (in week 12)
Complete layout drawing to be presented to lab instructors.

10 A.M. Monday December 9
Complete parts drawing, an assembly drawing, and a short design report due in Room ___.

12:00 Noon December 10
Design Presentations

APPENDIX C Schedule and Problems from "Architectural Design - Level One"

ARCHITECTURAL DESIGN - LEVEL ONE

Semester Schedule

Week	Studio activity
1	General introduction to the class for all level one students Organization; introduction and discussion of Project 1 sketch problems
2	Lecture on kinds of drawings, graphic materials and techniques; design crits
3	Introduction of Project 2 (Analysis of Urban Housing); discussion Fieldwork (outside class) by study teams Fieldwork (outside class) by study teams
4	Fieldwork (outside class) by study teams Fieldwork (outside class) by some; consultations in class for others General review of Project 2; introduction of Project 3 (A Feasibility Study)
5	Illustrated lecture by visiting landscape architect; discussion of Project 3 Lecture on preliminary site analysis Fieldwork (for some); design crits
6	(vacation) Design crits at student desks Design crits at student desks
7	General review of Project 3 Conclusion of general review; practice in freehand drawing Practice in and review of freehand drawings; perspective methods
8	(vacation) Written survey made of class response to work thus far; practice with perspective Exercises in graphic delineation: trees, shades and shadows
9	Introduction and discussion of Project 4 (Site Plan and Unit Design); individual student reviews Lecture on house design, basic construction, and landscape materials
10	Individual student reviews Individual student review; desk crits Desk crits

Semester Schedule (continued)

Week	Studio activity
11	Desk crits Desk crits Desk crits
12	Preliminary review Desk crits (vacation)
13	Desk crits Desk crits Desk crits
14	Desk crits Project 4 handed in at 5:00 p.m. (no class)
	Review of Project 4 (all day session during exam period)

ARCHITECTURAL DESIGN - LEVEL ONE

20 units - Professor Harris, in charge
Ms. Lewis, instructor

This studio is intended as the first architectural design studio for its enrollees;it has no formal prerequisites, but early in the term a census will reveal which students have studied the introductory drawing class and special assistance will be made available to any who have not.

The primary objective of the studio will be to obtain perspective on the issues involved in residential design both at the neighborhood level and in the individual dwelling unit. A secondary but important objective will be to practice analytical problem-identification-and-solving procedures and skills in graphic representation that are essential to all architectural intervention.

In the first half of the term there will be several one-week sketch design problems with focus on identifiable subsets of residential issues such as detailed arrangement of private quarters and site planning to maximize ecological benefits for residential use. These assignments will be alternated with analytical exercises to examine a number of existing urban residential neighborhoods and to compare them with respect to the satisfactions they appear to confer on residents and the physical character of their development. The sketch problems will be individual effort, the analytical exercises carried out by teams.

In the second half of the term students will individually choose from a number of proposed sites in the vicinity on which to develop their personal design for housing up to 40 families at a density of about 15 families per acre.

These studies are expected to provide recurring need for accurate measurement, evaluation of choices, making policy decisions, constructing graphic reports on conditions and possibilities, and providing creative design input on scales ranging at least from 1" = 100' to 1" - 4'. Documentation and presentation will adhere to the formats proposed under MIRS and each student will be expected to maintain complete documentation at 8 1/2 x 11 of the shared studio materials, his own personal contribution in the studio, the work of his colleagues where of interest, as well as any other collateral activity attesting to his progress in representational skills and architectural knowledge.

This studio expects to be physically adjacent to that directed by Professor Kirk and Professor James. Because of the considerable overlap in subject matter it is intended to share largely, especially in the first weeks of the term, the sketch problem subjects, analytical studies, group discussions and critiques, lectures, slide shows, exhibitions of background materials, and general faculty advice.

Ample time will be reserved at the end of term for group review and discussion of the work accomplished, and for personal counseling. Individual evaluation will depend heavily on cumulative evidence of productive work. Quantitative effort is important, but secondary to qualitative merit especially as concerns the project proposals of the final design.

ARCHITECTURAL DESIGN - LEVEL ONE

Sketch Problem - Vacation in the Caribbean

On one of the Caribbean Islands a property is to be developed for a small hotel having most of its units at ground level under the site conditions defined in the attached diagram. Your problem is the design of a typical unit to fit these conditions.

Most vacationers will have reservations and will arrive by taxi from the coral jetport to the hotel's central building housing the office, the lounges, the dining areas, and the other common facilities. Their luggage will be taken to the assigned unit via the path running along the south. To the north the unit will have direct frontage on the amenities of the natural beach.

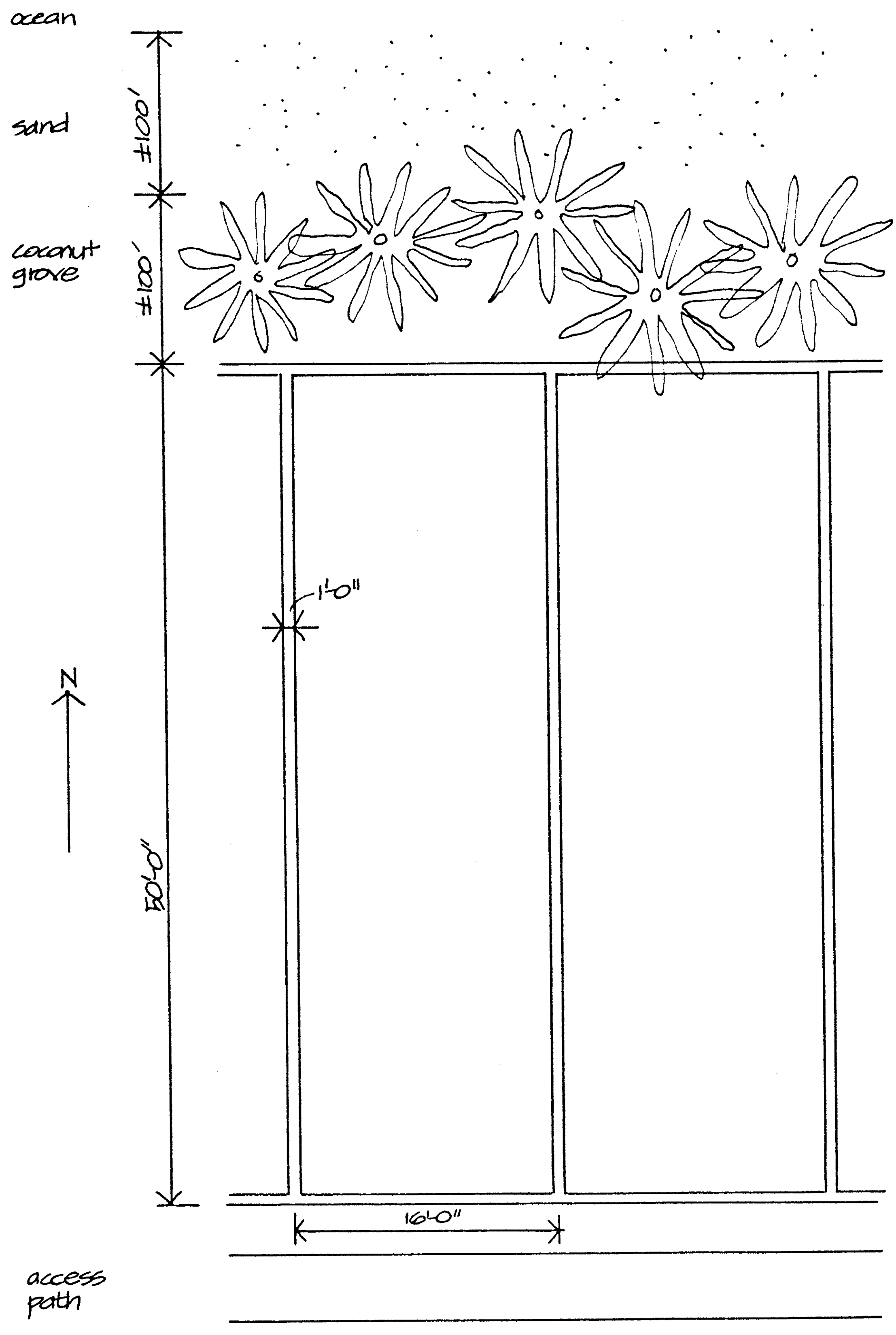
By any standard this will be a luxury accommodation priced in the winter at roughly $100/day per couple, with meals. Well-to-do honeymooners, prosperous executives and professional people, and elderly couples with ample savings, will be typical guests in the season. In the off-season the hotel will seek contracts with package tour people at lower rates. Guests will not bring a family of children along, though it might be well to have enough space to provide a crib or cot for an occasional tot of preschool age, or to allow for an adult threesome.

Though luxurious, life for the visitor is much simpler than at home. The climate is unfailingly benign, and the cool moist tradewind is steadily from the NE. Insects are not troublesome. One spends the day outdoors, on or in the water, at sports, or exploring the tropical forest. There need hardly be any distinction between indoors and outdoors except for the desire for privacy and the need for protection from the rains, which are frequent but short. Evenings would be largely taken up with a leisurely restaurant dinner often followed by some kind of entertainment featuring local musicians and dancers.

Your imagination should conjure up the accommodations appropriate to this situation, helped by the following observations. Some guests will bring a fairly showy wardrobe; their activity will generate a brisk traffic in clothes to be laundered and pressed, and the need for storage of suitcases, sports gear, etc. You must accommodate hobbies: photography, scuba diving, golf, nature studies. Bathroom routine might be enhanced by the availability of a small private piscine. Our guests will want enough kitchen gear to generate their own breakfasts and snacks, and they may wish to entertain friends for cocktails without receiving them into boudoir intimacy. Some private outdoor sunning space, with a few exotic plants, birds, and lizards, could enrich the inward experience.

Present your studies in plan and sections and/or model 1/4" = 1'-0", showing all the relevant furniture and built-in equipment.

VACATION IN THE CARIBBEAN



ARCHITECTURAL DESIGN - LEVEL ONE

Sketch Problem - Summer on the Southeast Coast

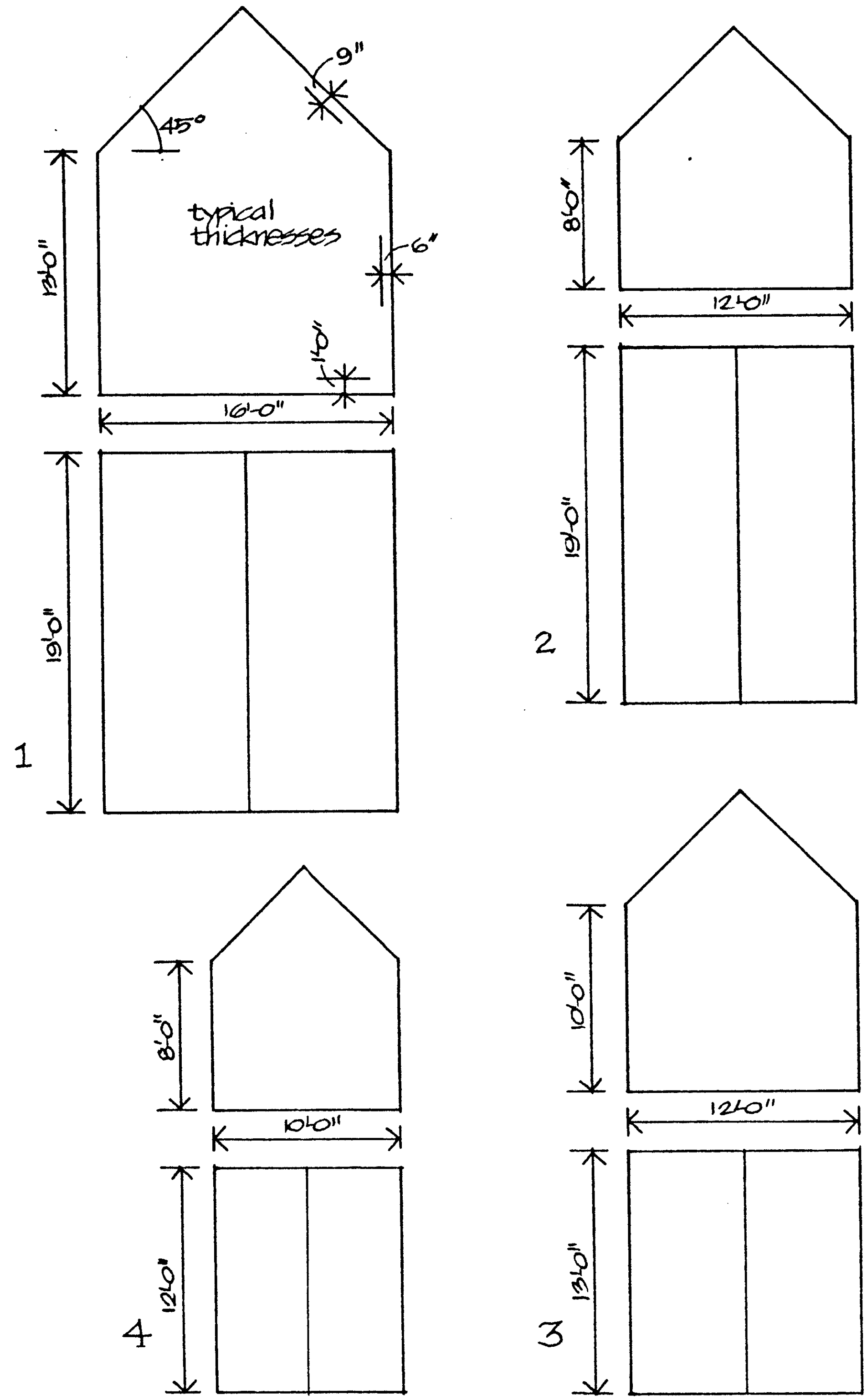
Somewhere on the American coast south of Cape Hatteras the local fishermen have been in the habit of building simple work-houses in wood frame. Now this mode is giving way to non industrialized commercial fishing less conducive to individual enterprise. Your client for this exercise has easily accumulated four sheds in good condition whose dimensions and roof forms are indicated in the accompanying diagram. These are rather easily transportable and he wishes to assemble them on his property so as to constitute as attractive seasonal rental facility suitable for a small family (up to four if this proves feasible).

He wants to locate this house (cottage?) somewhere in a large level grove of live oaks, from under whose branches one can look eastward over the dunes to the open sea. Electricity and municipal water are available, there is bottled gas for cooking, and the soil conditions are excellent for leaching septic wastes.

In approaching this problem you will need to deal with trade-offs of many kinds and decide according to your value judgements; for example a certain amplitude of dimension may be obtainable only by cutting down the size of family to be lodged, but you should avoid constructing any new space insofar as possible. The sheds are for the most part lacking in interior finish (which you may wish to add) but the advantage is that the structural members are exposed and can rather easily be adapted to accept doors, windows, dormers, and dhimneys wherever these are needed.

A few practical suggestions: if one is to avoid the artificial environment provided by air-conditioning, free air movement everywhere is necessary not only for warm weather comfort but to inhibit mildew and rot; the shade of trees is all-important in avoiding solar heat gain; insects can be a problem, and some screened and roofed area is needed for sedentary outdoor activities; the provision of even a rudimentary heating device would greatly prolong the period of usefulness into the spring, fall and even winter which can be especially appealing to those who enjoy outdoor activity in bracing weather.

But his is also a problem in form; you must pay especial attention to the geometry of roof intersections, and it would be well if you could present a simpler block model in addition to the conventional drawings at 1/4" = 1'-0".


9"
45°
typical thicknesses
6"
13'-0"
1'-0"
16'-0"
19'-0"
1
8'-0"
12'-0"
19'-0"
2
8'-0"
10'-0"
12'-0"
4
10'-0"
12'-0"
13'-0"
3

ARCHITECTURAL DESIGN - LEVEL ONE

Sketch Problem - Sojourn in the Maghreb

You have a surprise client who expects to spend several years on business near a northwest African city (which could be Fes, Algiers, or Tunis). He has located, in a suburb, a part of an old house (they would call it a palace) that could be altered into an apartment for his use. This house is being subdivided into apartments accessible from what was the principal central atrium; its characteristics are devoted in the accompanying diagram.

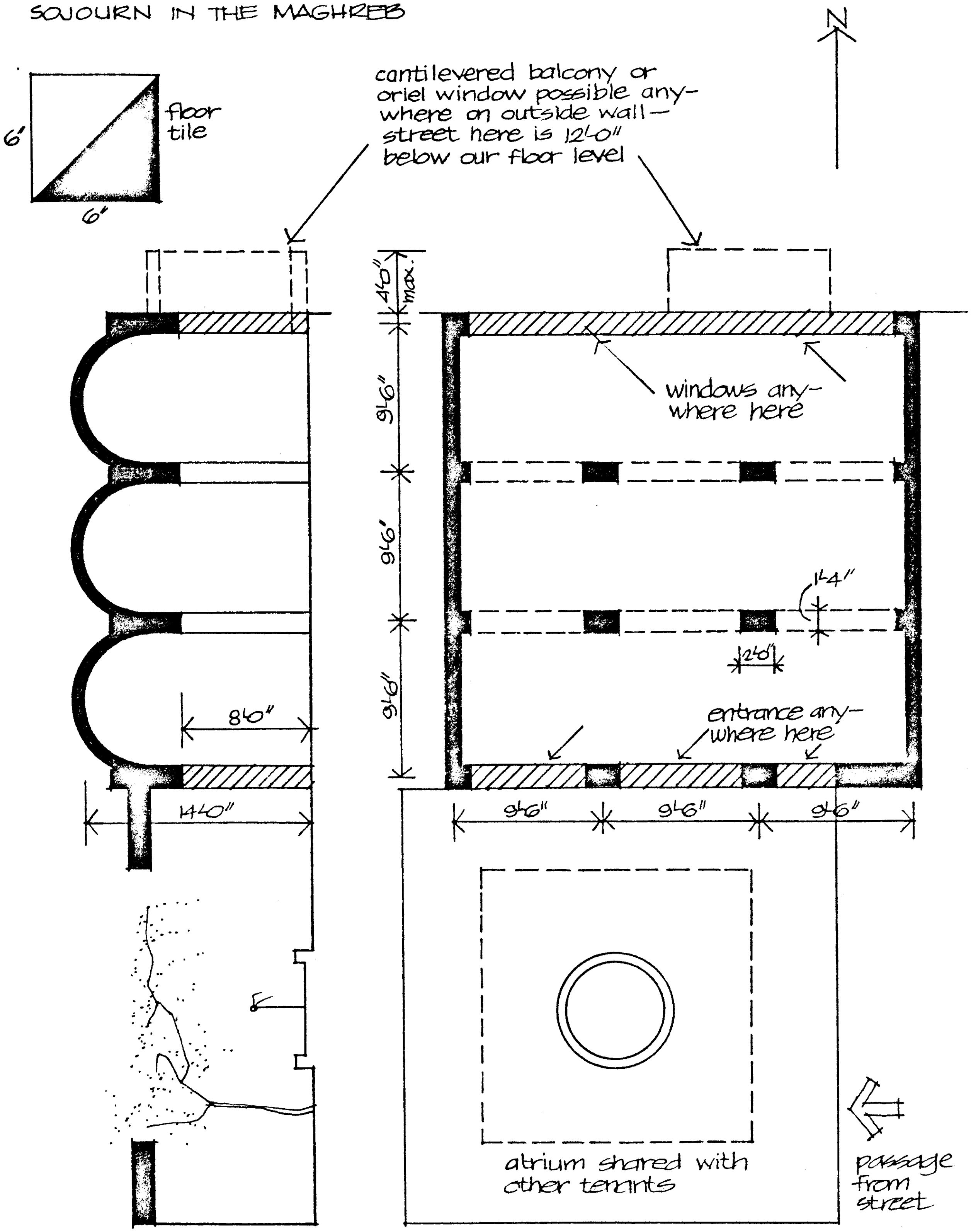
The available space is peculiar in that it inherits the idiom of traditional construction in the region, executed in soft-brick masonry and based on parallel barrel vaults of very short span. Simple reinforced concrete beams permit the transverse flow of space from vault to vault. This had been the architecture of necessity in the absence of wood, stone, steel, and industrial capability. Horizontally the resulting spaces are smaller in scale than those we are accustomed to, but they are relieved by the lofty height of the vaults.

You may assume that modern plumbing installation may be achieved, and that power is available to operate an air-conditioning unit (located in a convenient furred space) which would take the place of natural ventilation. Not very much daylight is needed in that climate, but it is obvious that windows on the public atrium would lack privacy; hence thought should be given to a small private atrium of some limited skylights (this is the top floor) but be careful about unwanted heat gain in this connection. Winter can be cold and some kind of heat is essential during that period.

As to the life-style of your client, he is a bachelor in his early forties. He will see and entertain his business associates mostly in restaurants and cafes, but sometimes he will have guests for dinner. At these times he will avail himself to the services of local people who can cook and serve. Likewise such resource people will take care of routine housecleaning and food shopping whilst he is about his work in town. Yet he is a man who likes to get away from office concerns when he can and to relax at home with books and music (he is even working at a novel) and he will have relatively little opportunity to develop new friendships among people of his own nationality and interests. So provide as best you can for the inward-looking man when he has time on his hands.

If you find that the arrangement partitions, built-in equipment and major furniture comes rather quickly (owing to an insufficient range of choice), you could spend some time preparing a recommendation for the layout of floor tile. Your client has purchased at a very advantageous price 4,000 pieces of 6"x6" tile divided diagonally into equal halves of black and white. Investigate whether with this 'given' you could nevertheless give individual character to the use areas you have planned.

The scale of 1/4" = 1'-0" is indicated for the presentation drawings.


N
6'
6'
floor tile
cantilevered balcony or oriel window possible any-where on outside wall—street here is 12'-0" below our floor level
4'-0" max.
9'-6"
9'-6'
9'-6"
windows any-where here
1'-4"
2'-0"
entrance any-where here
8'-0"
14'-0"
9'-6"
9'-6"
9'-6"
atrium shared with other tenants
passage from street

ARCHITECTURAL DESIGN - LEVEL ONE

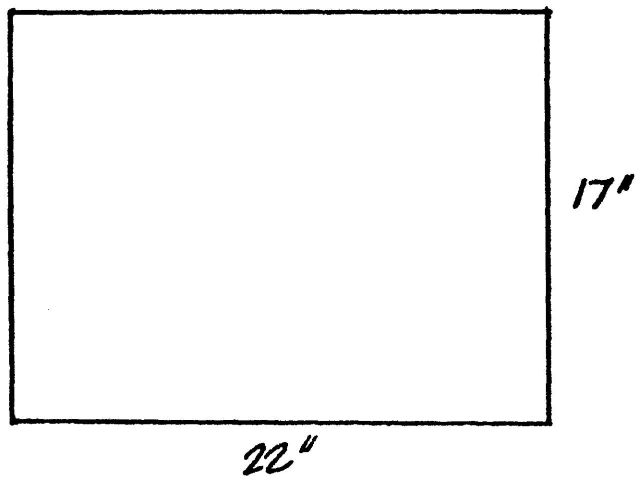
Project 2 - Analysis of Urban Housing

This exercise is an inquiry into the morphology of urban residence, with an attempt to observe relations between the form and structure of communities and the behavior and well-being of the inhabitants. It is believed that the project will provide a data base and raise issues helpful to the later attempt to design new housing facilities in the two studios concerned.

A number of residential localities easily accessible in surrounding communities will be selected for study. To each locality will be assigned two teams of investigators. The FAR tear will prepare a graphic, verbal, and statistical description of the entire locality, which will not exceed 300 acres. The NEAR team will focus its detailed examination on a small part of the locality not to exceed 12 acres, selected so as to represent most accurately the characteristic attributes of that locality.

It will be important to be able to compare one locality or housing group with the others. To this end the teams are asked to arrange their reports according to formats described below. All presentations will be in black on white paper 17" x 22".

SHEET SIZE AND USE FOR PLANS 1,2,3,4 AND SKETCHES



EACH SHEET SHOULD SHOW:

1. NORTH ARROW (NORTH ROUGHLY UP PREFERRED)
2. NAME OF LOCALITY OR DWELLING GROUP
3. LEGEND
4. LAND USE GRAPH (PLANS 2, 3 AND 4)
5. VISUAL SCALE
6. SHEET SHOWING SKETCHES OF DWELLING GROUP NEED NOT INCLUDE THE ABOVE INFORMATION EXCEPT NAME OF LOCALITY OR DWELLING GROUP.

FORMAT FOR GRAPHICS:

- DRAWINGS WILL BE MADE IN BLACK INK ON HEAVY TRACING PAPER
- PENS TO BE USED ARE KOH-I-NOOR RAPIDOGRAPH TYPE. POINT SIZES TO BE USED ARE #1, #2½ AND #4.
- USES OF PEN SIZES, LINE, TONE AND LETTERING TYPES ARE AS FOLLOWS

LOCALITY SCALE (FAR) 1" = 200'

LOCALITY PLAN (PLAN 1)

THE LOCALITY PLAN WILL BE PROVIDED: IT WILL BE USED FOR SURVEY PURPOSES AS WELL AS TO BE THE BASE MAP FOR A LAND USE OVERLAY

LOCALITY LAND USE MAP (PLAN 2)

STREETS AND PARKING	
RESIDENTIAL	(LETRATONE) LT 149
COMMERCIAL	LT 910
INDUSTRIAL	LT 118
PARKS AND PLAYGROUNDS	LT 922
INSTITUTIONAL	LT 907

WITH ABBREVIATIONS
IN LETRASET 47-14 CLN
HELVETICA MEDIUM CAPS:

HEALTH	H
POST OFFICE	PO
SOCIAL SERVICES	SS
PARKING	PK
POLICE	P
FIRE	F
SCHOOLS	PS (PRIMARY)
	MS (MIDDLE)
	HS (HIGH)
CHURCH	C
RECREATION	R
LIBRARY	L

(LOCALITY LAND USE MAP (PLAN 2) CONTINUED)

TRANSIT LINES IN 1/8" CHARTPAK TAPE:

BUS ROUTE (B) ← BUS STOP
RAPID TRANSIT (T) ← TRANSIT STOP

POSITION OF DWELLING GROUP OUTLINED IN 1/16" CHARTPAK TAPE

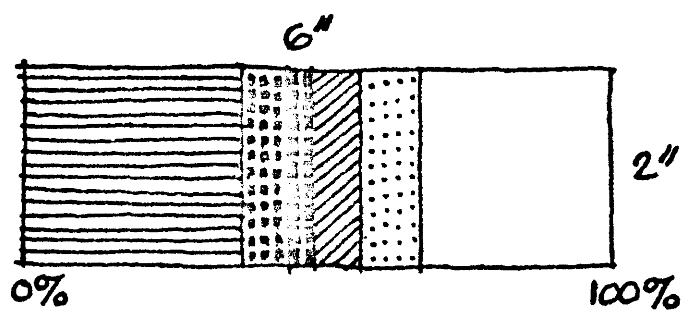
CIRCLES FROM CENTER OF DWELLING GROUP
5 MINUTE WALK 1200' RADIUS #2½ PEN
10 MINUTE WALK 2400' RADIUS #2½ PEN

LAND USE GRAPH

TO SHOW % OF:

A) PRIVATE OWNERSHIP
1) RESIDENTIAL
2) COMMERCIAL
3) INDUSTRIAL

B) PUBLIC OWNERSHIP
4) PARKS AND PLAYGROUNDS
5) INSTITUTIONAL (W/ ABBREV.)
6) STREETS AND OTHER PUBLIC WAYS OR LANDS



SHOW IN ORDER LISTED ABOVE USING SAME SYMBOLS AS FOR LAND USE MAP

DWELLING GROUP SCALE (NEAR) 1" = 40'

DWELLING GROUP (PLAN 3) TO SHOW:

STREET, SIDEWALKS #1 PEN SOLID LINE

BLOCK BOUNDARIES #1 PEN SOLID LINE

PROPERTY LINES #1 PEN BROKEN LINE W/ DOT

CONTOURS #1 PEN BROKEN LINE

BUILDING OUTLINES #4 PEN SOLID LINE
(WALL THICKNESS TO SCALE)

OPEN FENCES #2½ PEN

SOLID WALLS #2½ PEN

TREES (OVER 20') #2½ PEN

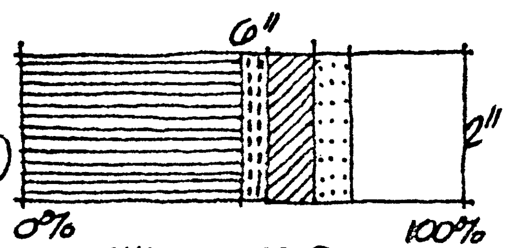
HEDGES #2½ PEN

BUSHES (LARGE) #2½ PEN

LAND USE GRAPH TO SHOW % OF:

A) PRIVATE OWNERSHIP
1) RESIDENTIAL
2) COMMERCIAL
3) INDUSTRIAL (IF APPLICABLE)

B) PUBLIC OWNERSHIP
4) PARKS AND PLAYGROUNDS
5) INSTITUTIONAL (W/ ABBREV.)
6) STREETS



SHOW IN ORDER LISTED USING SAME SYMBOLS AS FOR LOCALITY LAND USE MAP

SECTION THROUGH SITE

ELEMENTS CUT IN SECTION #2½ PEN SOLID LINE
ALL OBJECTS IN ELEVATION BEYOND #1 PEN SOLID LINE

DWELLING GROUP TERRITORIALITY CATEGORIES (PLAN 4)

TO ILLUSTRATE PUBLIC, SEMI PUBLIC, PRIVATE USE OF LAND

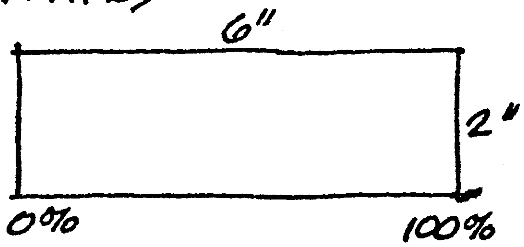
EXTERIOR: PUBLIC USE

SEMI PUBLIC USE — LT 127 (LETRATONE)

PRIVATE USE — LT 91 (LETRATONE)

TERRITORIALITY GRAPH (BAR TYPE)

SHOW CATEGORIES ABOVE USING SYMBOLS ABOVE



GATHERING PLACES #2 1/2 PEN

(NUMBER IN CENTER OF CIRCLE-REFER TO DESCRIPTION OF ACTIVITY AND GROUP INVOLVED)

2

INTERIORS: RESIDENCES — LT 91

COMMERCIAL — LT 127

INSTITUTIONAL

STREETS, BLOCKS, PROPERTY LINES, TREES, BUILDINGS ETC. SHOULD BE REPRESENTED AS IN DWELLING GROUP (PLAN 3).

DWELLING GROUP GRAPHIC ILLUSTRATIONS

SKETCHES (FROM PHOTOGRAPHIC SLIDES OR FREE HAND) ILLUSTRATING SPATIAL QUALITIES OR ACTIVITIES. THESE SHOULD BE PRODUCED TO FIT INTO A 17" X 22" FORMAT. (SEE SHEET SIZE REQUIREMENT.)

ARCHITECTURAL DESIGN - LEVEL ONE

The Sketch Portfolio

An important objective of this class is to encourage you to develop the power to express concepts graphically. We have emphasized your need to collect a personal record at 8 1/2 x 11 of original drawings or their reproduction, both those done in the course of assigned studio work and others done just for additional practice. On Friday November 1 we will receive your portfolios as they have progressed during the first half of the term, for review, appraisal, and criticism.

You may be having difficulty getting started on the habit of thus expressing yourself. We suggest that you set aside an hour or more a week during which to work at this skill. Attached is a list of possible topics. Whenever you can, give form to these concepts without consulting documents. If you don't know what it is, look it up and then draw your version. If you don't know how it should look, look at a picture of it and then draw your version. Make these sketches quickly and freely with some black marker on white paper. Make them joyfully; this is not meant to be tedious work.

1. Exploded axonometric to show how brick fireplaces are usually made.
2. Plan, section, and elevation of a London taxi.
3. Large-scale leaf cluster of quercus alba.
4. Early American house with two dormers and an elm.
5. Medieval fortress with its reflection in water.
6. Colleoni on his pedestal.
7. Worm's-eye view of your favorite automobile.
8. Agave tequilana.
9. Icosahedron (several views).
10. Relief map of Scotland.
11. Still-life with fruit.
12. Diagram to illustrate the golden section.
13. Violin family in proportion.
14. The Parthenon as originally built.
15. Gadus callarias Linnaeus.

The Sketch Portfolio (continued)

16. Yawl in a yard.

17. Your design for a teapot.

18. Triceratops.

19. Flying buttress.

20. Tomb arranged like Napoleon's.

21. Balachino in St. Peter's, Rome.

22. Suspension bridge.

23. 16th century armor.

24. Henry IV (of Navarre) on a bicycle.

25. U.S. Cavalry saddle.

26. Squinch, or better still, a pendentive.

27. Homerus americanus.

28. Windsor chair.

29. Gear train of a windmill grinding flour.

30. Triticum vulgare.

31. Viking ship.

32. Minaret.

33. Rose window.

34. Vault system in ambulatory of Chartres.

35. Ketch in the Keys.

36. Conch.

37. Paved floor in cosmati.

38. Bird's-eye axonometric of this campus.

39. Cumulus clouds.

40. Timber barn frame.

41. Family picnic.

42. Macbeth witches.

ARCHITECTURAL DESIGN - LEVEL ONE

Problem 3 - A Feasibility Study

The purpose of this exercise is to compare the suitability of several sites for the development of group housing as described below. A number of sites will be proposed. Each student is to choose one of them for his study and to explore a configuration of streets, house lots, and buildings that meets the program requirements of that parcel.

The density target is 36 persons per acre, or 15 dwelling units per acre at 2.4 persons per family (which is slightly larger than the average family size in this city.) In order to achieve such density without depriving people of adequate living conditions, a space budget will insure to each person his fair share of space regardless of size of family:

family indoor space	350	s.f. per person
family outdoor space	350	s.f. per person
parking space	100	s.f. per person
public outdoor space	400	s.f. per person
	1200	s.f. needed for each person

The allowance for parking includes the space occupied by one vehicle for each two persons; the access to parking space is included in the public space allotment. People will of course prefer a private garage on the family lot, but the access to such garages may consume an inordinate share of public outdoor space, and you will have to weigh this against collective parking with pedestrian walks to the houses in which case people should not have to walk more than 200 feet to their door, and new problems will arise about the removal of solid wastes, the access for moving vans, ambulances, fire fighting equipment, and other occasional emergency vehicles.

The space budget per person should be understood as an average figure. As we penetrate into this study, we will find that the areas will have to be skewed to allow more areas per person for small families and less for larger families (one person living along cannot get along with one-fourth the kitchen needed by a family of four).

Our initial assumptions also allow for the possibility of meeting the density target by means of 100% one-story construction. By resorting to two or even three-story construction the building coverage may be reduced by 1/2 or 2/3, resulting in more private and/or public outdoor space for the target density, but with considerable loss of privacy in family outdoor space unless heroic steps are taken to cut off overview of neighbor's space.

By family outdoor space we mean space private to the family on the ground, not on some other family's roof. In cases of even higher density the latter is of course better than nothing.

Problem 3 - A Feasibility Study (continued)

The tendency in this immediate metropolitan area has been for a slow shrinkage in population with a trend toward smaller family size; larger families are more likely to gravitate to the suburbs. However, it is desired in this project to provide for a wide range of family size, and also to include for not less than 16 elderly people. The tentative distribution is:

24%	of people living in accommodations for the elderly
10%	of people living in families of 7 to 8 persons
12%	of people living in families of 4 to 5 persons
18%	of people living in families of 3 persons
33%	of people living in families of 2 persons
3%	of people living in families of one person
100%	

Sites are being proposed that approximate 100,000 s.f. (2.3 acres, almost one hectare). On a site of that area, the distribution of dwelling units would be:

Elderly	20 persons
1 family of 8	8 persons
3 families of 4	12 persons
5 families of 3	15 persons
14 families of 2	28 persons
2 families of 1	2 persons
25 DU plus elderly	85 persons

For sites that are greater or less than 100,000 s.f., the DU's should be adjusted so as to maintain an average of 1200 s.f. per person with untis distributed in approximately the same proportion as above.

All presentation is to be at 1" = 40'-0".

ARCHITECTURAL DESIGN - LEVEL ONE

Guidelines for Major Term Project

We have now begun work on the major term project, the design of a small residential neighborhood. Lectures and general reviews will be less frequent. You will be expected to study your design continuously as an iterative process, drawing and modeling at several scales, and producing new material for direct criticism about once a week.

The following is proposed as a target for the distribution of family sizes (in percentage of persons in each size family)

19% - 6 members or more
15% - 5 members
24% - 4 members
24% - 3 members
18% - 2 members or less

In order to encourage the incorporation of multistory buildings, family private outdoor space on the ground should be provided for approximately only half the DU's; these should be predominantly but not exclusively for larger families. DU's without private ground space should have a balcony or terrace at least 120 s.f. This change will permit a somewhat higher density per acre.

The inclusion of a separate institution for elderly housing is optional. When included, its characteristics should reflect one of the types described in the studio dealing with elderly housing.

The car-parking requirement is reduced to one for every three persons.

Final presentation will include site plan and section at 1/40" = 1'-0" (include immediate surroundings); plan, section, and elevation of from four to six contiguous DU's at 1/8" = 1'-0"; furniture plan of at least one unit at 1/4" = 1'-0"; and one or more models at the indicated scales.

Project is due 5:00 P.M. Friday December 13. Final reviews for all Level One studios are all day Monday December 16 and all day Tuesday December 17. Instructors will be available for personal counseling in the remaining days of that week.

APPENDIX D - INTERVIEW MATERIALS

AN EXPLANATORY NOTE ABOUT THE REPERTORY GRID TESTS

George Kelly, in _The Psychology of Personal Constructs_ (1955), originated the Repertory Grid Test as a psychological technique for eliciting a person's constructs about the behavior of other people whom he knew.

> We started out with two notions: (1) first, viewed in the perspective of the centuries, man might be seen as an incipient scientist, and (2) that each individual man formulates in his own way constructs through which he views the world of events. As a scientist, man seeks to predict, and thus control, the course of events. It follows, then, that the constructs which he formulates are intended to aid him in his predictive efforts.

While the test was originally intended for use in psychology, Roger Simmonds adapted it for use in the investigation of design education to obtain the student's constructs built around teachers and other students. Using the repertory grid provided a mechanism for obtaining these perceptions in the student's own words.

Students were first handed the Teacher Repertory Grid sheet (A) and asked to write on it the names of eight different teachers they had encountered who fit the descriptions listed there. The interviewer, working from the blank grid sheet (C), next asked:

> If you consider the teaching behavior of teachers 1, 2, and 3, was there some way in which two of them were alike and one was different? How was (the specified teacher) different?

On the grid sheet row marked "1,2,3", the student's response (including a specific example if possible) was written down in the column labeled "Constructs"; a check mark was placed in the column under the number of the teacher identified as being different; and cross marks were placed in the columns of the remaining two teacher's numbers. This signified that the checked teacher was identified as having the construct while the other two teachers did not. Next in order, teachers 3,4, and 6 were considered; the same questions were asked and the answer was recorded in a similar way. This process continued until more comparisons did not seem to produce new constructs.

The student was then asked to take the sheet on which the interviewer had been writing and, after the interview, to check over his constructs as recorded for accuracy and completeness, then to fill in the remaining squares of the grid with either a check or a cross, depending on whether the construct identified did or did not apply to each of the remaining five individuals on the row.

The Student Repertory Grid was conducted in a like manner.

The examples shown on the following pages are those used for the architects; appropriate changes were made on the sheets used for testing the engineers.

THE TEACHER REPERTORY GRID (Sheet A)

We want to find out how students and faculty think about the process of educating architects. In order to do so we want to use George Kelly's Repertory Grid Tests. In these tests we ask you to talk about and compare the teaching and learning behavior of faculty and students you know.

So that you can feel free to be completely candid about these people, we have worked out a process whereby only you know their names.

This page is to elicit the names of the people we want you to talk about. You keep the page and we will never see it.

Next to the descriptions of eight people whom you will have encountered, please write their names. Please do not use the same name twice.

No.	Description	Name
1.	The best studio teacher you have encountered.	1
2.	A teacher who taught you a lot about architecture.	2
3.	A bad studio teacher or assistant you have encountered.	3
4.	Another poor teacher of architecture.	4
5.	A good teacher in a lecture course you have taken.	5
6.	A poor teacher in a lecture course you have taken.	6
7.	Another teacher or assistant whose architecture course you took.	7
8.	And another teacher.	8

THE STUDENT REPERTORY GRID (Sheet B)

Next to the description of 8 students whom you will have encountered, please put their names. Please do not use the same name twice.

You will keep this page; we have no need to know the names of the students you use.

No.	Description	Name
1.	One of the best students you have encountered in a studio.	1
2.	A student who will make a fine architect.	2
3.	One of the worst students you have encountered in a studio.	3
4.	A student you think will make a bad architect.	4
5.	A friend who has worked in a studio with you.	5
6.	A good student you encountered in a seminar.	6
7.	A poor student in a seminar.	7
8.	Another student you can think of.	8

(Sheet C)

REPERTORY GRID SHEETS

GRID TYPE

name.................

date.................

PERSON NO.	1,2,3	3,4,6	6,7,8	1,3,5	1,6,8	2,4,7	2,7,8	2,3,6	3,5,7	4,6,8	5,6,7	1,2,4	3,5,8	1,5,6	4,6,7
1.															
2.															
3.															
4.															
5.															
6.															
7.															
8.															

NOTES

CONSTRUCTS

APPENDIX E   Informal Design Experiment Outcomes - Chair Design

Near the end of the interview, the student was handed a blank tablet of 8 1/2" x 11" white paper and asked, "Would you design a chair?" Listed below are the comments and questions responding to this request; the statements in parentheses are those of the interviewer. The prefix ME identifies mechanical engineering students; the prefix A denotes architecture students.

ME1 Any particular type? (That's for you to decide.)
I'm not very good at drawing but there it is.

ME2 Any kind of chair? (That kind would you like to design?)
OK, I think of chairs I like and those are what I will do.
I'm used to my ruler; I can't draw straight lines anymore.

ME3

ME4 How do you design a chair? I can draw a chair. That's like designing a piece of paper.
You want a complete chair - not part by part? (The whole chair, no parts, would be fine.)
Any special kind of chair? (Design it for a child.)

ME5 Just a chair - or a new kind of chair?
Any particular kind of chair? (Design it for a child.)
I can't draw - that's why I studied drafting.
When I was a kid, I always liked a big chair that you could get yourself buried in. It was not made especially for kids.
I'm trying to think of something innovative.

ME6 A chair? How would I design a chair?
Well, I've seen chairs collapse...
That's all you said - design a chair? (Yes.)
I don't know how my freehand sketching is this time of year. I'll start with a side view.

ME7 Can I look at one? (Yes.)
Do you want dimensions, like when Professor Baker asks you to design a disc brake? (Dimensions are not necessary here.)
Do you want an image of a chair? (No, design a chair.)
I can design a chair that does not look like a chair. (Fine.)
Do you want three views? (No, what you have is OK.)

ME8

A1 Can it be a chair I like? (Yes.)
Is it for a table - to sit in or talk to people in? If it is for a kitchen it would be different than if it were for a living room. (Do whatever you feel is right.)
I will do what's easiest to draw.

A2 Just a chair - that's the only thing you want? (Yes.)
Do you want this done fast? (Take about five minutes perhaps.)
Is a schematic drawing sufficient? (Yes.)

A3 (groan) Can I make notes about what it is to be? (Yes.)

A4 Any specific kind? Do you want to be the client? (OK.)
What are your desires - where is it to be used?
at a desk or table?
to sit up straight or lean back?
soft or hard?
with arms?
to surround with comfort?

A5 A chair? Want a quick one? (Take about five minutes.)

A6 A chair...oh boy..ah me...
One thing - is this for anyone in particular? (It probably should be, don't you think?)
Where is it to be used - at a desk, sitting for conversation, in a lobby... (Design it for a children's playschool.)
I will probably be thinking back to what I liked.

A7 A chair, a chair...
I have to do all my sketching in plan, section, and elevation since I can't do perspective.

A8 This is the toughest thing I'll have to do all day.

A9 Just a simple chair - anything in particular? (Design it for a child.)
Plan or elevation (Either or both is OK.)
It has got to be nice and comfortable.
Do you mind if I make it a rocking chair? I like rocking chairs. (That's fine.)
It should be comfortable, the kind you sit down in and then fall asleep in.
I'm not very good at drawing.

A10 I look around, I see a chair.
It's not a very original design.

A11 (laugh) What is this? I just finished telling you I can't draw.

A12 A chair...
The first requirement of this chair is that it have lots of space around it - it's a wing chair.
Excuse me if the drawing is not quite level.

A13 What would I like to be sitting in?

A14 What kind of chair would you like? A chair for me? (Design it for a child.)
If I can draw good...
It's what I wanted when I was a kid - nice and soft and big.

A15 (nothing said)

A16 In profile or in plan? (Either way is OK.)

Note: I had not anticipated the number of 'what kind of a chair' type questions, and I became concerned that my non-committal response was not encouraging students to ask further questions. About a third of the way through the interview schedule, therefore, I began responding to the 'what kind of a chair' question by asking that the chair be designed for a child. Of the four students who were asked to design for a child, A6, A9, A14, and ME5, none pushed his query further.

APPENDIX F Informal Design Experiment Outcomes - Shoe Design

Students were asked to list the kinds of information they would wish to have in order to design a pair of shoes.

ME1

1) foot size
2) type of shoe needed - work shoe or what
3) type of materials which fit the constraints of 2
4) must take into consideration appearance
5) need some type of idea of machines available to produce shoe so that new shoe can be made on old machine or slightly modified machine
6) should consider physics of shoe-foot-body.

ME2

1. for what purpose (basketball, symphonies)
2. cost (in relation to materials and technical construction)
3. comfort (do they have yo merely decorate, protect, support, and in what proportion)
4. style (high top? with or without laces?)
5. shoe size.

ME3

ME4

purpose
size of foot
desired style
durability vs. comfort and elegance.

ME5

1. foot size
2. characteristic desired (comfort + look)
3. use intended for
4. how are shoes usually made.

ME6

1) What terrain are they to be used on (water, rock, sand, etc.)
2) Is there any odd chemical composition present (fumes, gases, solvents?)
3) Weight of person.
4) Type of activity to be used for (tennis, skindiving, rock climbing etc.? oh yes, walking?)
5) Profile of stride nec.
6) Desired life of shoe.

ME7

1) For whom do you want the shoes? (male, female, child)
2) For what purpose do you want the shoes? (sport, safety in the factories or fashion)
3) Size and approximately the model? (ie. high heel)
4) The cover material which I have to use.

ME8

A1

1. Do you like your shoes tight or loose?
2. Do you prefer ties or slip ons?
3. What sort of leather - smooth, fine-grained, rough grained, suede? If do not want leather might prefer canvas because it is washable.
4. What sort of sole material? Leather - which can be replaced and which produces slick, hard walking surface-- Rubber - not repairable, quiet, cushioned.
5. What sort of heel - height outside shoe
   depth inside shoe
   shape
   material
6. What are they to be used for?

A2

1. Range of users -- footsizes, weights
2. Range of uses -- hiking, swimming, fishing, boating, city walking, lounging
   -- impacts on extent to which aesthetic must be accommodated -
3. Eventual cost -- development, to buyer
4. Materials available
   -- note that "meta question of how they are interrelated, and relative importance of them is mentioned only here

A3

length of foot
width of foot at widest part
width of foot at heal
whether person wished to be taller or same height
length of foot from ball to end of big toe
whether person wished to have to untie or unbuckle them or if they should be slip on
color preferences
occasion for which shoe is to be worn
other clothes with which shoe is to be worn.

A4

SHOES - specific pair or general type

Size plus
+
number of toes
sex of user
use intended
height
ease of putting on or taking off
weather protection
appearance
material

A5

Facts: 1) dimensions of the feet
2) purpose - snow boot? or whatever
3) cost
4) material available

I'll need, then, my sensibilities.

A6 WHAT USES? Sports, casual?
WHO? Profession, (gender), everyone?
WHERE/WHEN? Climate, location
WHAT PLEASES PEOPLE IN LOOKS? Colors, fabrics
PHYSICAL CONSIDERATIONS Arches, are laces good...Heel ht.

A7

1. Dimensions of the feet for which the shoes are being designed for.
2. Information about how the foot acts under varying conditions of use, e.g. walking, running.
3. Style preferences of person for whom shoes are designed (if any).
4. Activity for which shoes will be worn, e.g. sports, daily wear, standing alot, walking alot, etc.
5. Information about the foot concerning how its posutre and use affect the comfort of the rest of the body.

A8 Men's or women's
Age of wearer
How durable
Where they would be worn
Something of wearer's personality.

A9 Who are they for?
How big is he/she + his/her feet?
What colors are preferred?
What will these shoes be used for mainly:
climbing,
walking,
playing sports,
mud-walking,
etc.
How long should they be designed to last?
How much should they cost?
What materials should be used?

A10 How would they be used - lot of walking, running, standing, sitting
Any problems with feet or legs
Type of shoe preferred
Kinds of shoe that are liked and disliked.

A11 How much the consumer walks.
What kind of ground the consumer walks on.
How much the consumer sits.
How much is indoors. - (feet get hot)
Whether consumer has any problems with ordinary shoes - in style or comfort, etc.
How cold or hot the climate is.

A12 What sort of feel do you want?
Type of weather?
Socks?
How much walking? standing? sitting?
Do you care about appearance or is performance of prime importance?

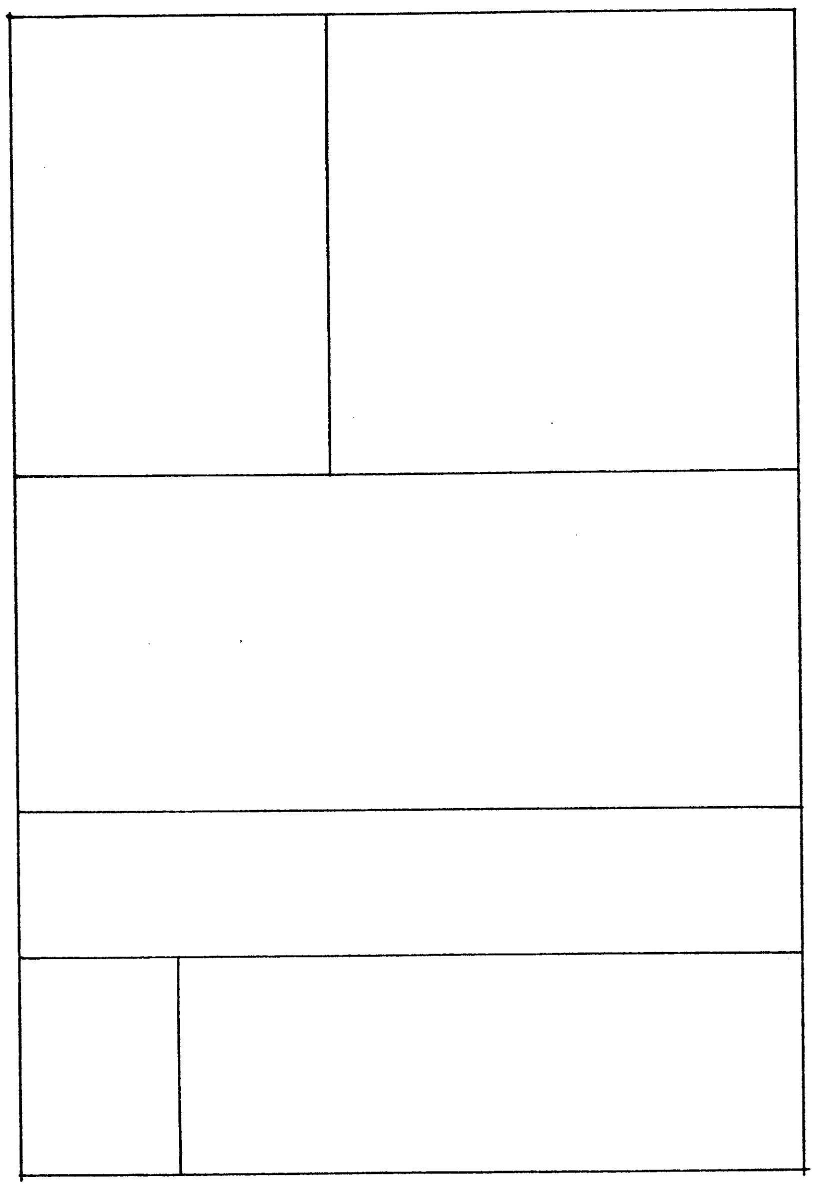
A13 -<u>foot</u>
-where to be used - climate and formal/informal
-how much user could afford
-basically what user wanted - high heel - low heel material preferences

A14 Who is it for. for what purposes.
How long should it last.
Should it be for long walking, warmth, or is it for evening style, only for indoors.
Will the wearer use it more than once. (rich or poor person)

A15 Size of foot
person
what he/she wanted
income
comfort
materials - qualities related (to wants)
aesthetic parameters (also related to wants)

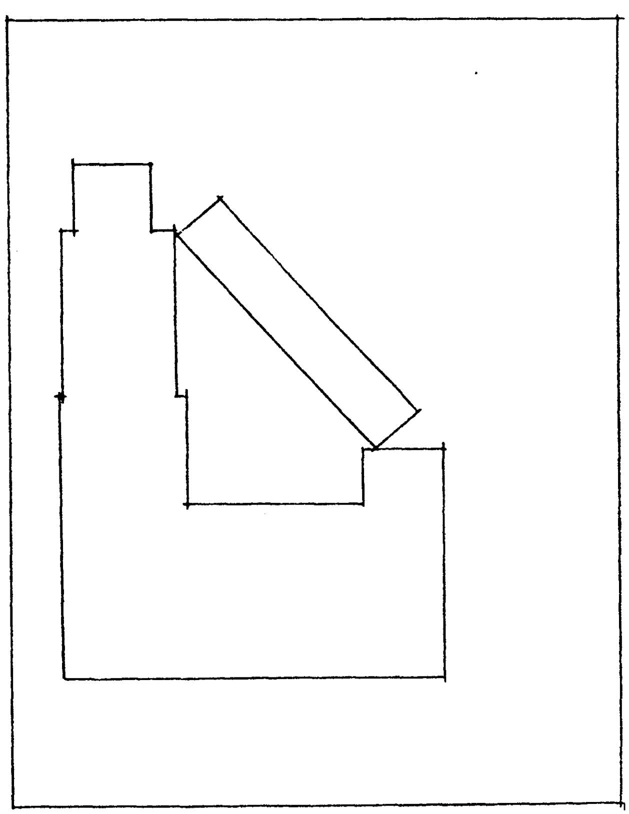
A16 -size
-use (running, walking, formal&c)
-ht. of user - wants heel?
-how active user is
  -kind of matls
  -durability
  -looks or for show
-if user is more
  -masculine or fem
  -self-confident
  -that's enough.

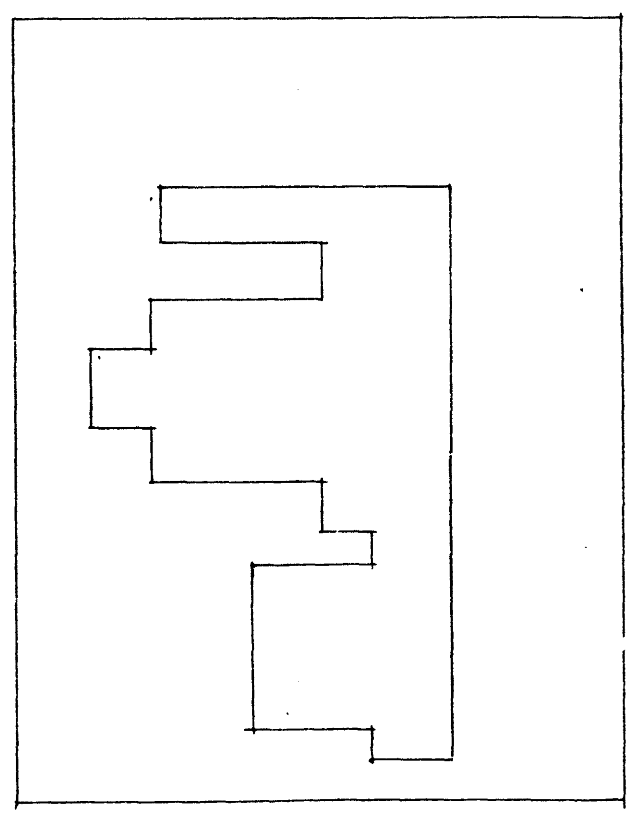
APPENDIX G Informal Design Experiment Outcomes - Visual Design

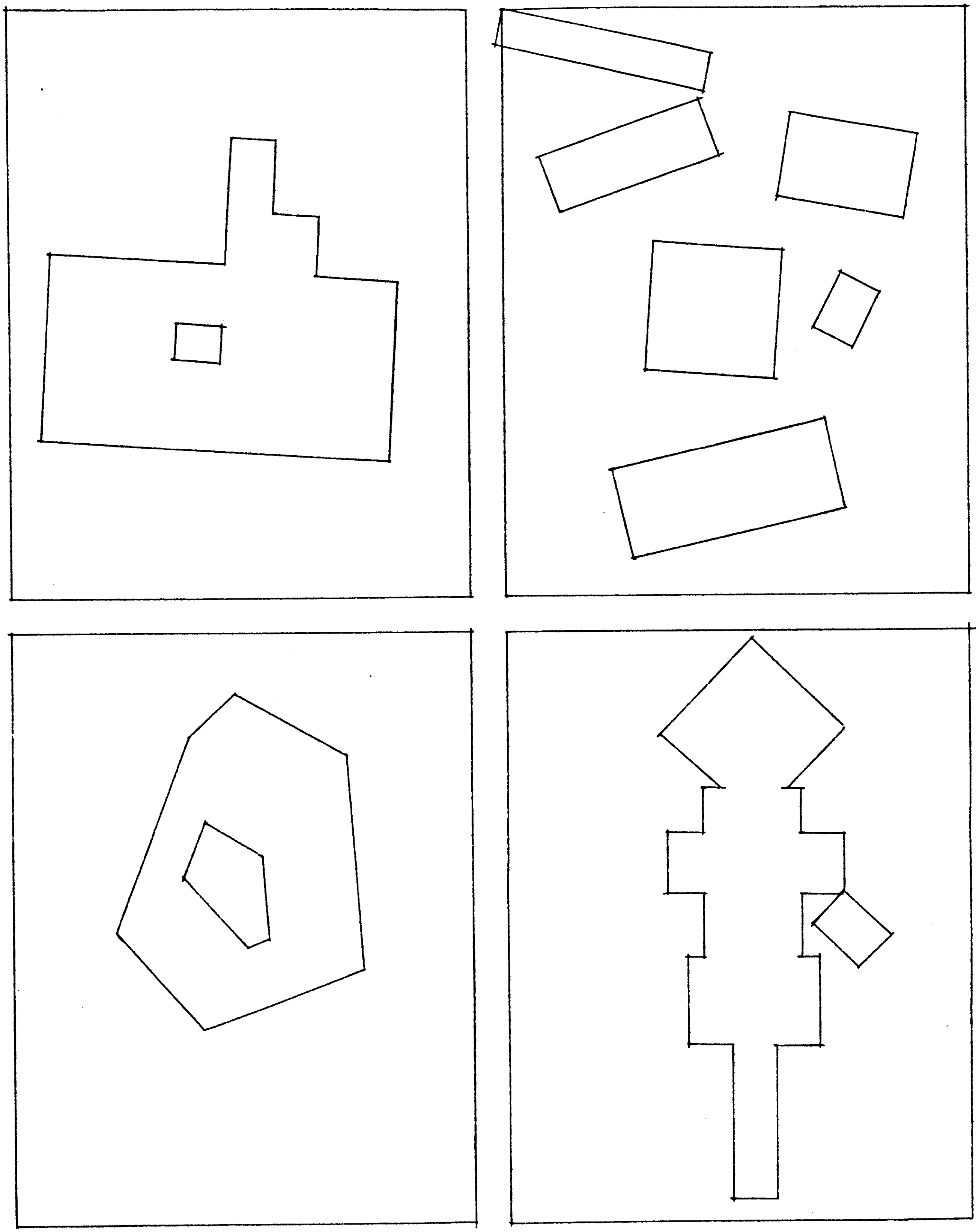


The above drawing shows the way a 4" x 6" card was divided to produce six rectangles for the visual design exercise. Drawings on the next six pages illustrate, at reduced scale, twenty designs produced by various designers.

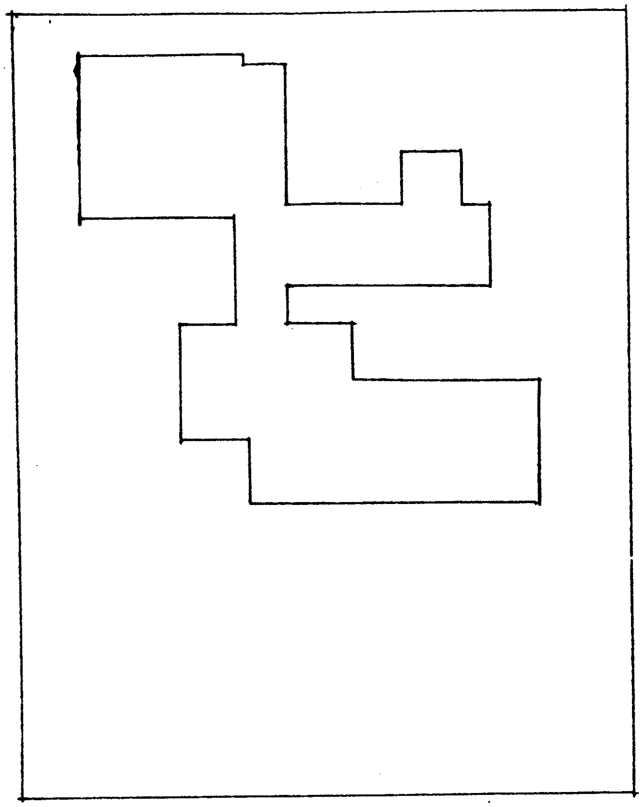
The following six designs were made by students from the mechanical engineering beginning design class.

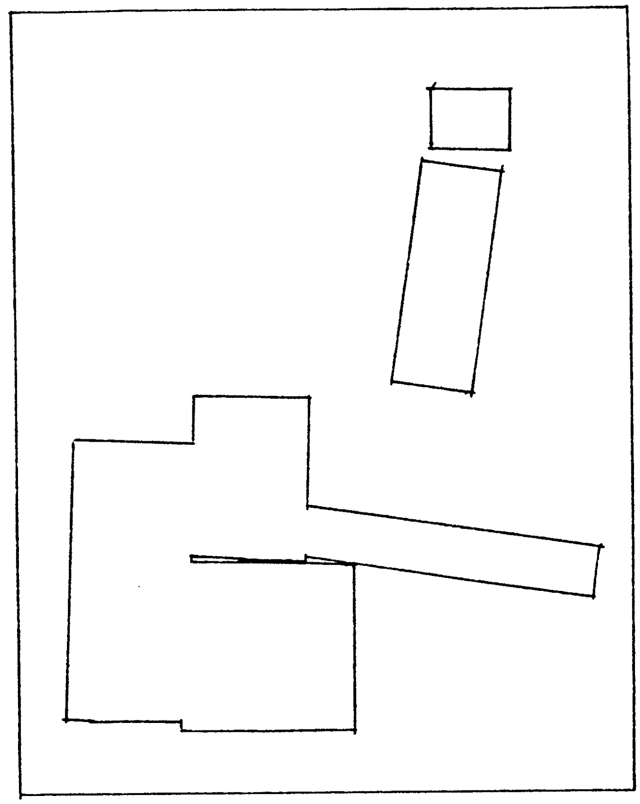


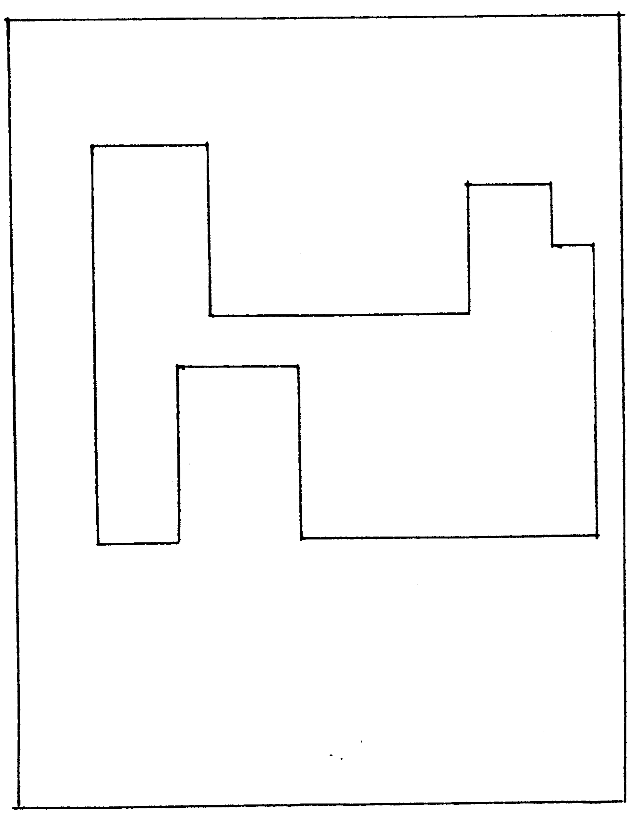


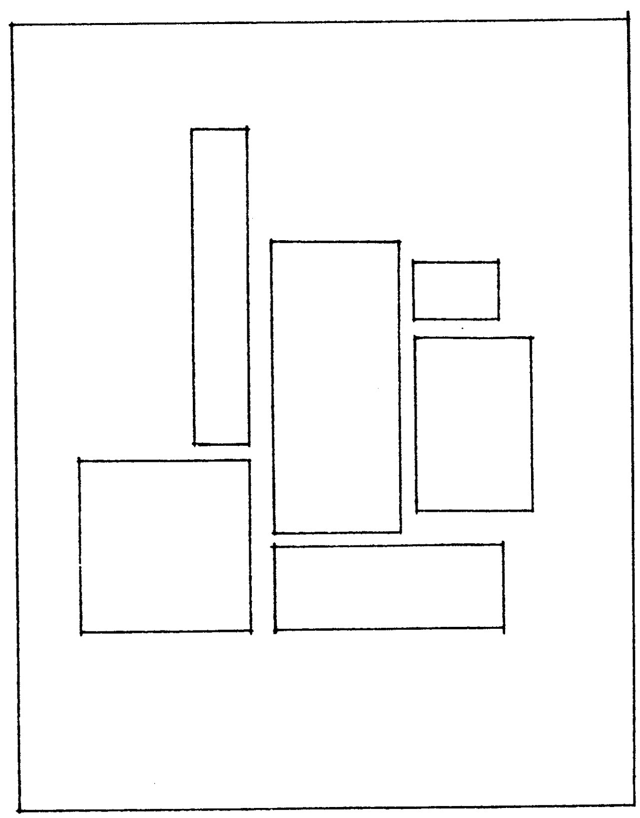


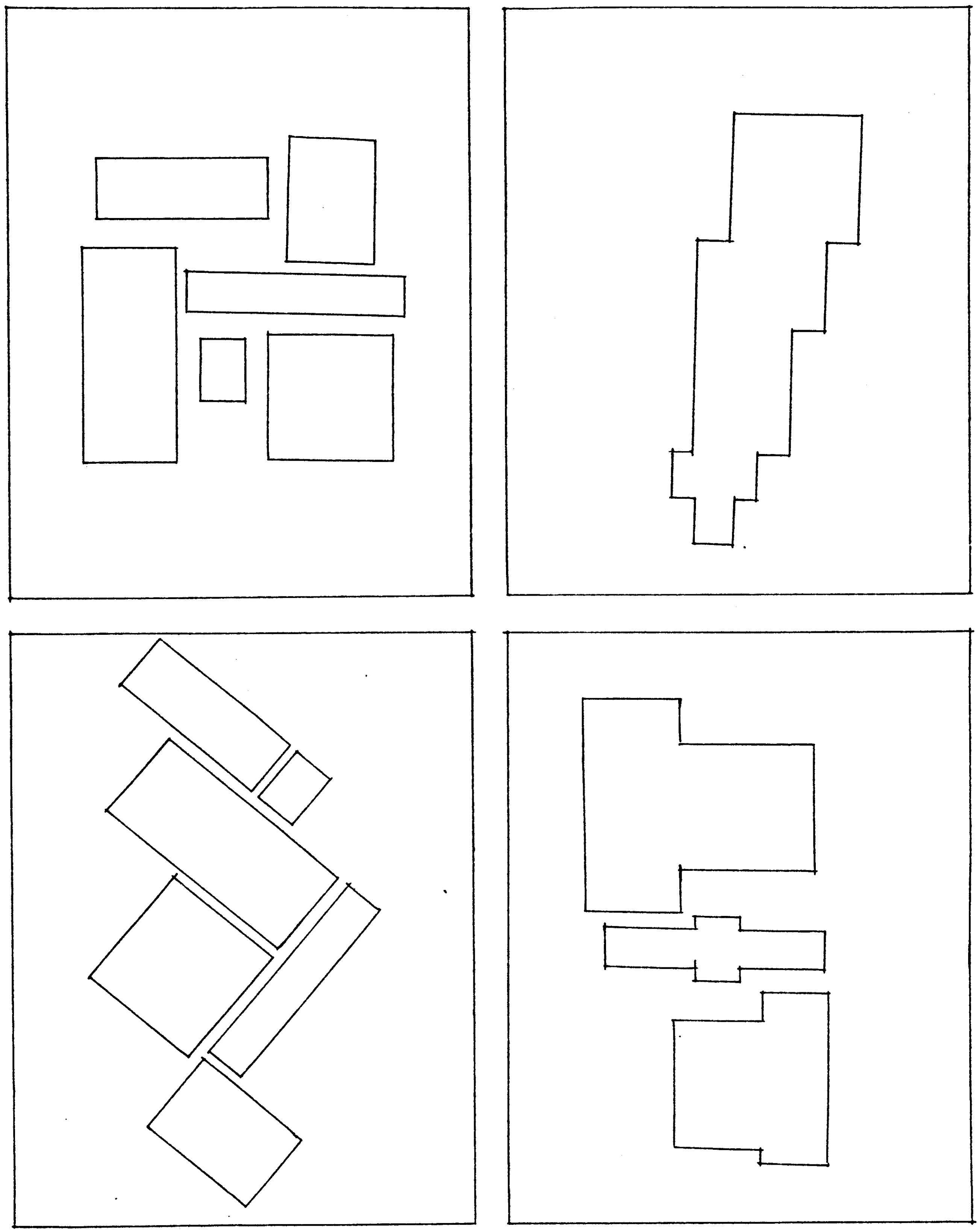
The following eight designs were made by students in the beginning architectural design studio.











The following six designs were made by graduate designers in either architecture or engineering.